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THE NEW ELEMENTS OF CLÈVEITE GAS.

By J. R. RYDBERG.

THE excellent investigations of Runge and Paschen on the spectrum of clèveite gas[1] have made the existence of another new element besides helium very probable.[2] But the method of forming the spectral series seems to rest upon rather an insecure basis, although by the help of the relation between the principal series and the sharp series (second subordinate series of Kayser and Runge), which I long ago pointed out, it would have been very easy to state clearly the true connection. The relation in question, which comprehends the above mentioned series in a single common formula, is derived from the observation that the first term of a principal series forms at the same time the first term of the corresponding sharp series, or, to state the same thing in another form—

The difference between the common limit of the nebulous and the sharp series and the limit of the corresponding principal series gives the wave-number[3] *of the common first term of the sharp and the principal series.*

If we designate the limits of the series by D (nebulous), S

[1] ASTROPHYSICAL JOURNAL, 3, 4–28, 1896.

[2] For the new elements I use the symbols A (Argon), He (Helium), Pa (Parhelium).

[3] By *wave-number* I mean the number of waves in 1^{cm}. See *Svenska Vetensk. Akad. Handl.*, 23. 35, 1890.

(sharp), P (principal series), the order of the series by subscripts to the symbols of the elements (stronger series 1, weaker 2), and the mean of D and S by M, we have for the alkali-metals:

	D	S	M	P
Li	28582.92	28582.16	28582.54	43482.53
Na_1	24468.89	24471.36	24470.13	41452.61
Na_2	24486.08	24488.55	24487.32	41452.61
K_1	21959.52	21951.39	21955.46	35008.92
K_2	22017.37	22009.24	22013.31	35008.92
Rb_1	20861.25	20877.05	20869.15	33706.66
Rb_2	21098.83	.....	21098.83	33705.59

Hence, if we call P_1 the first term of a principal series, we have

	P—M	P_1	Diff.
Li	14899.99	14903.03	— 3.04
Na_1	16982.48	16972.70	+ 9.78
Na_2	16965.29	16955.51	+ 9.78
K_1	13053.46	13041.72	+ 11.74
K	12995.61	12984.63	+ 10.98
Rb_1	12837.51	12798.95	+ 38.56
Rb_2	12606.76	12575.18	+ 31.58

For Pa and He, on calculating the limits by the same method which I have used for the other elements, I have found the following values:

	D	S	M	P
Pa	27174.47	27175.00	27174.74	32032.53
He	29222.70	29222.63	29222.67	38452.89

where the connection of the series is still undecided. By using the above mentioned relation in the calculation of the values of P_1, two combinations present themselves, *viz.*,

	P	M	P—M	P_1 Obs.	Diff.	Mean error
Pa	32032.53	27174.74	4857.79	4900.65	— 42.86	20
He	38452.89	29222.67	9230.22	8950.14	+ 280.08	40
and						
Pa	38452.89	27174.74	11278.15	.....	.....	..
He	32032.53	29222.67	2809.86	.....	.....	..

Although the calculated values of P_1 differ very considerably from the observed values, there can be no doubt that the first combination, which is the one chosen by Runge and Paschen, is the only possible one, for the lines calculated from the second were not observed. We meet here with the not very common case in which the calculated values greatly surpass the observations in accuracy, the limits of error for the values of M and P amounting at most to one unit, while the mean errors of the two values of P_1, determined with the bolometer, are 20 and 40 respectively. The differences found certainly exceed the errors to be expected, but the analogy with the spectra of the alkali-metals speaks so decisively in favor of an exact agreement between the values of P_1 and $P-M$, that I do not hesitate to ascribe the differences to errors of observation.

In order to judge better of the possibility of such differences I have examined the observations of Runge and Paschen, first reducing to wave-lengths the extreme values of the angular determinations (Runge and Paschen, p. 27). Thus we find:

Observed maximum	Observed minimum	Mean	Calculated value
21040	19500	20400	20580.0
11450	10540	11170	10831.0

whence it appears that the calculated values lie within the limits of the observations. A closer examination shows that the angular determinations group themselves about well-defined means, by no means symmetrically, but so that the greater values are much more numerous than the smaller ones, and at the same time more distant from the closely concentrated central groups At the line 11170 we even find two distinct groups. The distribution of the values is shown in the table on page 94.

The greater deviation of the larger values seems to indicate a broadening of the lines in the direction of the shorter wave-lengths. But, however this may be, the arithmetical mean of the observations under these circumstances gives by no means the most probable value of the quantity in question. I have there-

Wave-length according to R. and P.	Number of values	Range in angular values	Mean wave-length	Number of greater values	Number of smaller values	Difference from mean	
	of the central group					of greatest value	of smallest value
20400	7	0′.10	20580	12	3	2′.63	1′.17
11170_1	7	0′.15	11350	5	1	2′.32	0′.28
11170_2	9	0′.18	11190	4	2	1′.87	0′.73
7280	7	0′.10	7330	7	3	2′.82	0′.48

fore calculated the mean angular values of the central groups, and with the aid of the table (*loc. cit.*, p. 25), deduced the mean wave-lengths. For the first line the value thus obtained coincides exactly with the number calculated above; this, however, must be regarded as partly accidental. The third line does not agree as well as before, but still falls within the limits of the errors of observation. As to the second line, the doubling of the central group agrees perfectly with an hypothesis which had suggested itself previously and quite independently to explain the considerable discrepancy between observation and calculation. According to Runge and Paschen the strong Na lines in the visible and ultra-violet spectrum come out with great intensity; it could therefore scarcely be doubted that the line 11392.5 in the infra-red would also appear. It was also to be expected that in the bolometric determinations this line would form with the adjacent 10831.0 a single thermal maximum, and retain only a feeble indication of its double origin; the two thermal maxima, if they are still to be discerned as separate lines, ought at all events to appear very close together on account of the superposition.

But this is just what we have found, for according to Runge and Paschen the general mean of the wave-length determinations gives the value 11170, which would come out as the mean of the two wave-lengths mentioned above, if the intensity of the Na line were 1.5 times as great as that of the He line. The two values which I have calculated from the central groups of the observations would indicate a sharp Na line and a broad He line. The determinations do not, however, allow any perfectly definite conclusions to be drawn. But I believe that the preceding con-

siderations will suffice to prove the importance of making further measures of the two infra-red lines. The accuracy attained by Lewis in his bolometric measurements[1] would be quite sufficient to decide the present question. At all events I do not doubt that the calculated values 4858 and 9230 will be found for the wave-numbers of the lines *in vacuo*.

In this connection I cannot refrain from mentioning that the two new elements of clèveite gas as well as argon seem to be subject to a regularity regarding their atomic weights, to which I called attention some years ago.[2] The rule in question may be expressed as follows:

If the atomic weights of the elements, which form the first rows of the periodic system, be reduced to the nearest integral numbers, the elements of uneven valency will have the form 4n–1 and the elements of even valency the form 4n.

On account of the uncertainty of the determinations of atomic weights and their increasing differences from integral numbers, the rule could be traced with some certainty only for the first 22 elements (to Fe inclusive). It shows here three exceptions, *viz.:* Be (9 instead of 8), N (14 instead of 15) and Sc (44 instead of 43), but it gives place for He (4) and A (20) as well as for an element with the atomic weight 3, which would possibly answer to Pa. Spaces remain for elements with the reduced atomic weights 36, 44 and 47. The series of numbers is shown in the table on page 96.

Of the six places formerly vacant in the present division two are probably permanently taken up by the new elements, He and A. According to analogy these elements should have an even valency, while Pa might possess an atomic weight 3 and an uneven valency. For further particulars, as well as for regularities which appear on advancing further in the series of the elements, I will refer to the paper mentioned above. It seems not quite impossible that the present exceptions may yet submit to the rule, when we consider the imperfection of our

[1] LEWIS, ASTROPHYSICAL JOURNAL, **2**, 1–25, 1895.

[2] *Svenska Vetensk. Akad. Handl.* **11**, No. 13, 1886.

knowledge of the metals of the so-called rare earths (Be and Sc) and keep in view the surprising discoveries of the impurities of nitrogen.

n	1	2	3	4	5	6	7
Element	Pa	Li	B	N	Fl	Na	Al
P	?	7.01	10.9	14.01	19.06	22.995	27.04
4n — 1	3	7	11	(15)	19	23	27
Element	He	Be	C	O	A	Mg	Li
P	4.0	9.03	11.97	15.96	19.94	24.3	28.3
4n	4	(8)	12	16	20	24	28
n	8	9	10	11	12	13	14
Element	P	Cl	K	Sc	—	V	Mn
P	30.96	35.37	39.03	43.97	—	51.1	54.8
4n — 1	31	35	39	(43)	47	51	55
Element	S	—	Ca	—	Ti	Cr	Fe
P	31.98	—	39.91	—	48.0	52.0	55.88
4n	32	36	40	44	48	52	56

It is hardly possible that the approximation of the atomic weights to integral numbers, the correspondence in the number of elements in the two series of different valencies, and in the simultaneous evenness and unevenness of the integral numbers and the valencies, can be a mere chance.

The vacant places which still exist between Sc and Ti, as wel as between the corresponding terms of the following periods, seem only to add further support to the rule proposed, inasmuch as they afford very necessary space for the numerous metals of the rare earths.

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OUTLINES OF A THEORY OF SPIRAL AND PLANETARY NEBULÆ.

By E. J. WILCZYNSKI.

THE remarkable objects known as spiral nebulæ early attracted the attention of astronomers. There can be no doubt that they represent an important stage in the development of stellar systems. In this paper I shall attempt, without making any hypotheses, to explain their peculiar form. A number of other results will be obtained, and the general process of the evolution of nebular systems will present itself, but the full discussion of these interesting subjects must be reserved for another occasion.

This theory presented itself to me while engaged in investigations of quite a different kind, and it will be useful if we start out from the same point of view. If a swarm of meteors, say spherical in the beginning, revolves around the Sun, according to Schiaparelli, one of two things can happen. Either the mutual attraction of the meteors is great enough to resist the dissolving influence of the Sun, or this is not the case. In the latter case the dissolution will take place, and finally a ring of meteoric matter will result, filling the entire orbit.

If we examine more closely how this spreading out of the swarm into a ring is effected, we find some remarkable results. If, for the sake of simplicity, we assume that the swarm's center of gravity describes a circle around the Sun, we can also assume that all of the individual particles describe circles. For the dissolution can only take place if their mutual attraction is very small, and the act of dissolution itself diminishes the disturbing influence of their mutual attraction, by increasing the distances. Obviously all particles which describe the same circle constantly maintain their relative positions, but the particles in two different circles are in motion relative to one another. Let A and B (Fig. 1) be two points, whose orbits have the radii a and b res

pectively, where a is smaller than b. According to Kepler's third law, A will complete its circle sooner than B, so that when B has returned to its original position, A will be at A' instead of at A. After B has completed two revolutions A will be at A'', etc. Obviously the straight line AB is thus gradually spread out into a spiral whose coils continually multiply and approach

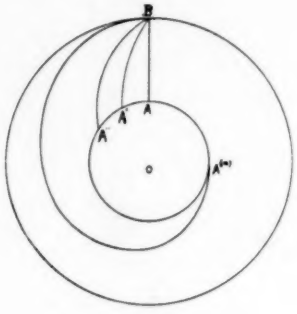

FIG. 1.

each other. Similarly every straight line of the original swarm is changed into a spiral, whose equation it would be easy to deduce.

The number of coils n obviously depends upon the time which has elapsed since the beginning of the process. If we assume that the motion takes place according to Kepler's third law, if a and b are the radii of the circles between which the entire spiral lies, and if ω_1 denotes the angular velocity of rotation for the inner circle, we have the following expression for the time which has elapsed since the beginning of the disintegration:

$$t = \frac{2n\pi}{\omega_1} \frac{1}{1 - \left(\frac{a}{b}\right)^{\frac{3}{2}}}.$$

The application of these results to spiral nebulæ is obvious. If in any irregular nebulous mass whatever a center of attraction has been formed, all long streaks and irregular masses of nebulous matter which remain, being subject to the law of gravitation,

must in the course of time assume a spiral form. Only those masses are excepted herefrom which are great enough to resist the dissolving influence of the center of attraction. Obviously our theory offers a possibility *of computing the time during which the nebula exists as a spiral.*

It must not be supposed from the above that we assume the nebulæ to consist of meteors. If we assume a gaseous constitution for them the results remain essentially the same. The attempt to prove this has led to the investigations contained in the following paper, ("Hydrodynamical Investigations of the Solar Rotation,") the application of which to the present case is easy to understand.

The theorems which are demonstrated there are of importance in the theory of planetary nebulæ. If the nebula (supposed gaseous) has the shape of a flat disk, if ω denotes the angular velocity of rotation, and ρ the density at the distance r from the center, where ω and ρ are supposed to depend only upon r, then

$$\frac{d^2\rho}{dr^2}+\frac{1}{r}\frac{d\rho}{dr}-\frac{1}{\rho}\left(\frac{d\rho}{dr}\right)^2+\frac{4\pi}{c}\rho^2=\frac{\rho}{c}\left(2\,\omega^2+r\frac{d\omega^2}{dr}\right).$$

This equation shows that in a planetary nebula of the above kind, whose temperature is the same throughout, the law of density $\rho=f(r)$ can be found if the law of rotation $\omega=g(r)$ is known, and conversely. In the first case we get two, and in the second case, one constant of integration. Now, $\rho=f(r)$ can frequently be obtained by measuring the brightness of the different parts of the nebula. We can therefore find ω, and would be able to determine the entire motion of the different parts of the nebula if we knew the value of ω for any one value of r. *We therefore have here an indirect method for observing motion in nebulæ.*

Further discussion of this and similar questions, as well as of the practical value of these results, whose theoretical value appears to me beyond doubt, must be deferred for the present. I believe that a discussion of photographs of nebulæ from this point of view would be of great interest.

With regard to the spiral nebulæ, I must add that many years ago Steven Alexander[1] held views which resemble the above in some particulars. Of all authors which I have been able to consult, Alexander is the only one whose explanation can be called scientific, while all others are more or less fanciful.

BERLIN, January 1896.

[1] STEVEN ALEXANDER, *Ast. Jour.*, 2.

HYDRODYNAMICAL INVESTIGATIONS OF THE SOLAR ROTATION.

By E. J. WILCZYNSKI.

SINCE the observations of Carrington first proved the remarkable law of the Sun's rotation, the observational material has greatly increased and the subject has been discussed by many eminent astronomers, among whom I will mention only Spoerer, Zöllner, Faye, and Tisserand. Theories have been proposed by Zöllner and Faye, which are far from being satisfactory. A memoir by Roche[1] on this subject is inaccessible to me. More recently Harzer[2] and Wilsing[3] have taken up the investigation, and doubtless they have found the correct method of treating the question. But their mathematical treatment is extremely complicated, and lacks rigor. The following investigation, which was completed before I knew of Harzer's and Wilsing's work, not only gives a perfect explanation of the solar rotation, but allows a great number of other questions to be put and partly answered, which have been hitherto considered unanswerable.

Let x, y, z be the rectangular coördinates of any point of a fluid, and a, b, c the values of x, y, z for a certain time $t = 0$. All of the points attract each other according to Newton's law of gravitation, so that a certain force acts upon every point. Let V be the potential of this force. Then, according to Lagrange's equations of hydrodynamics, we have:

$$\left.\begin{aligned} \frac{d^2x}{dt^2}\frac{dx}{da} + \frac{d^2y}{dt^2}\frac{dy}{da} + \frac{d^2z}{dt^2}\frac{dz}{da} &= \frac{d(V-P)}{da} \\ \frac{d^2x}{dt^2}\frac{dx}{db} + \frac{d^2y}{dt^2}\frac{dy}{db} + \frac{d^2z}{dt^2}\frac{dz}{db} &= \frac{d(V-P)}{db} \\ \frac{d^2x}{dt^2}\frac{dx}{dc} + \frac{d^2y}{dt^2}\frac{dy}{dc} + \frac{d^2z}{dt^2}\frac{dz}{dc} &= \frac{d(V-P)}{dc} \end{aligned}\right\} \qquad (1)$$

[1] ROCHE, *Mémoires de l'Académie des Sciences*, etc., Montpellier, Tome IX.

[2] HARZER, *A. N.*, 3026. [3] WILSING, *A. N.*, 3039.

in which we have put

$$P = \int \frac{dp}{\rho}, \tag{2}$$

where p denotes the pressure, and ρ the density for the point x, y, z. In addition to these equations we have:

$$\frac{d(\rho D)}{dt} = 0, \tag{3}$$

where

$$D = \begin{vmatrix} \frac{dx}{da}, & \frac{dx}{db}, & \frac{dx}{dc} \\ \frac{dy}{da}, & \frac{dy}{db}, & \frac{dy}{dc} \\ \frac{dz}{da}, & \frac{dz}{db}, & \frac{dz}{dc} \end{vmatrix} \tag{4}$$[1]

It must be noted that the general term fluid includes the incompressible fluids and gases as special cases.

We will now assume that the whole mass is in rotation about the axis of z, so that

$$x = \sqrt{a^2 + b^2} \cos \omega t, \quad y = \sqrt{a^2 + b^2} \sin \omega t, \quad z = \text{const.} = c, \tag{5}$$

where ω is the angular velocity of rotation, which need not be the same everywhere, but depends upon a, b, c. From (5) we find by differentiation:

$$\begin{cases} \frac{d^2 x}{dt^2} = -\omega^2 \sqrt{a^2 + b^2} \cos \omega t, \text{ etc.} \\ \frac{dx}{da} = \frac{a}{\sqrt{a^2 + b^2}} \cos \omega t - \sqrt{a^2 + b^2} \frac{d\omega}{da} t \sin \omega t, \text{ etc.,} \end{cases}$$

and all derivatives of z are zero, except $\frac{dz}{dc}$, which is equal to unity. If we substitute these values in (1), a simple reduction gives

$$\frac{d(V-P)}{da} = -\omega^2 a, \quad \frac{d(V-P)}{db} = -\omega^2 b, \quad \frac{d(V-P)}{dc} = 0. \tag{6}$$

These equations show that $V - P$ does not depend upon c, and depends upon a and b only in so far as these quantities are contained in

$$r = \sqrt{a^2 + b^2} = \sqrt{x^2 + y^2}.$$

[1] *Cf.*, for instance, Kirchhoff's *Vorlesungen über Mechanik.*

The same result is manifestly true for ω^2, *i. e.*, ω^2 *is a function of* r *alone.* All conditions are then satisfied, for it is easy to prove that D vanishes, so that (3) is also satisfied.

From (6) we now deduce:

$$\frac{d(V-P)}{da} = \frac{d(V-P)}{dr}\frac{a}{r} = -\omega^2 a,$$

whence

$$V - P = -\int \omega^2 r\, dr. \tag{7}$$

According to Poisson's equation

$$\Delta V = \frac{d^2 V}{dx^2} + \frac{d^2 V}{dy^2} + \frac{d^2 V}{dz^2} = -4\pi\rho.$$

Consequently we find from (7):

$$-\Delta(V-P) = +4\pi\rho + \Delta P$$

$$= +\Delta\left[\int \omega^2 r\, dr\right] = 2\omega^2 + r\frac{d\omega^2}{dr}. \tag{8}$$

If the fluid is a gas, we have Mariotte's law:

$$p = a^2\rho, \qquad P = \int \frac{dp}{\rho} = a^2 \log \rho, \tag{9}$$

where a^2 is a constant depending upon the nature of the gas and upon the temperature. If the absolute temperature T is not the same throughout, and if we assume the fluid to be gaseous, we have:

$$p = c\rho T, \qquad P = c\int \rho \frac{dT + T d\rho}{\rho} = cT(1 + \log \rho). \tag{9a}$$

For (8) we shall then have

$$4\pi\rho + c\Delta T + c\Delta \log \rho = 2\omega^2 + r\frac{d\omega^2}{dr}, \tag{10}$$

which for the case of constant temperature reduces to

$$4\pi\rho + c\Delta \log \rho = 2\omega^2 + r\frac{d\omega^2}{dr}, \tag{10a}$$

an equation from which it is easy to deduce the one employed in our theory of planetary nebulæ.

Let us now identify our rotating mass with the Sun, which we will suppose to be spherical. According to our first result, ω depends only upon r, *i. e.*, all points whose perpendicular distance from the axis of rotation is the same have the same veloc-

ity of rotation. If we therefore regard the axis of rotation to be surrounded by a system of cylinders, all of the points situated upon the surface of one of these cylinders rotate with the same velocity. In other words, these cylindrical surfaces rotate as if they were solid. But from one cylinder to another ω changes according to a certain law, $\omega = f(r)$, which, according to (10), depends upon the distribution of temperature and pressure in the Sun's interior. Since we know nothing of these quantities, *it is impossible to deduce theoretically a formula for the solar rotation.* We cannot, therefore, agree with Herr Harzer that his formula is more than an empirical law.

But it is very important to note that if $\omega = f(r)$ is known from observation, *equation* (10) *gives a condition which the temperature and density of the solar interior must satisfy.* If it were possible to find a second condition of this kind, *it would be possible to find the laws according to which these quantities vary from point to point.* If the periodicity of the Sun-spots is a hydrodynamic phenomenon, such an equation would follow from it. To obtain the numerical values of temperature and density everywhere, it would still be necessary to know a number of constants, *viz.*, temperature and density upon any surface of constant temperature or density, and the Sun's mass, which is known. This gives the value of the integral

$$M = \iiint \rho \, dx \, dy \, dz .$$

Obviously the influence of friction, which we have neglected, will be a tendency toward uniform rotation. It is evident, however, that an enormous time is necessary before its influence becomes noticeable. It is this point with which Wilsing's paper is principally concerned.

There is one other point to which I would like to call attention. It has recently been established by Stratonoff[1] that the faculæ have a different law of rotation from the spots, so that in every latitude the spots rotate more slowly than the faculæ. This is perfectly in harmony with the above theory, if we assume that the faculæ occupy a higher level in the Sun than the spots. If S

[1] STRATONOFF, *A. N.*, 3344.

and F are a spot and a facula respectively in the same heliographic latitude ϕ, F is at a greater distance from the axis of rotation than S, and since the law of rotation is such that ω increases with the distance r, F must rotate more rapidly than S. Obviously the comparison of the spot rotation law with that of the faculæ gives a means for determining the difference in the

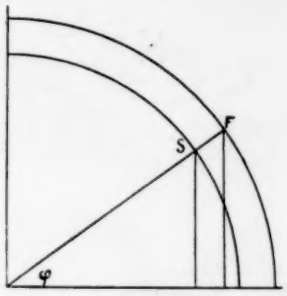

FIG. 2.

altitude of spots and faculæ or $S\,F$. The present material seems to indicate that this difference is considerable, almost $\frac{1}{60}$ of the solar radius. A similar comparison between the rotation of the spots and that of the photosphere as given by Dunér's spectroscopic observations indicates that *the spots are at a higher level than the photosphere*. The depth of the solar atmosphere between the photosphere and the faculæ is therefore probably very considerable, a result which agrees with the recent investigations of Messrs. Jewell, Humphreys and Mohler, who have likewise assigned a great depth to the reversing layer.

The full discussion of these questions must be deferred for the present. The Sun's law of rotation has not only been explained in a general manner, but we have been able to deduce important consequences from it. As for the main phenomenon itself, we now see that it would be a rather surprising fact if the Sun rotated like a solid mass, because this is only one of an infinite number of possible cases. The manner of the solar rotation is not to be wondered at, but it gives us a glimpse of the possibility of learning more about the Sun's interior condition.

BERLIN, January 1896.

PRELIMINARY TABLE OF SOLAR SPECTRUM WAVE-LENGTHS. XIV.[1]

By HENRY A. ROWLAND.

Wave-length	Substance	Intensity and Character	Wave-length	Substance	Intensity and Character
2975.587	Cr	0	2985.999	Cr?	000
2975.766		000	2986.109	Cr	000
2976.036		0 Nd?	2986.239		000
2976.191		000	2986.379		000
2976.316		000	2986.579	Cr	0
2976.801		000	2986.749		00 N
2977.021		00 Nd?	2986.999		0000
2977.331		000 N	2987.169		000
2978.151		000 N	2987.289		000
2978.316		0000 N?	2987.439 s	Fe?	000
2978.670		000 N	2987.959		0000 N
2979.480		00	2988.144		00 N
2979.670		0000 N	2988.333		000 N
2979.860		0 N	2988.598		000
2980.080		0 Nd?	2988.733	Cr	00
2980.330		00	2988.873		000
2980.490		000	2989.038[2]		0 N
2980.690	Cd?	00	2989.298		00
2980.915	Cr	0	2989.523		000
2981.070		00 N	2989.708		1
2981.990		000 N	2989.828		000
2982.180		00	2990.008		000
2982.340		000 N	2990.173		00
2982.530		00 N	2990.438		0
2982.885		000	2990.523	Fe?	1
2983.649[2] s	Ca, Fe?	0000 N	2990.718		00
2983.764		000 N	2990.788		000
2984.414		0000	2990.968		00
2984.654		00	2991.203		0
2984.849[3]		000 N d?	2991.318		0000
2985.119[4]		000 N d?	2991.538		000
2985.359		0000 N	2991.738		00
2985.439		0000 N	2992.188		000 Nd?
2985.629		000	2992.488		0000

[1] When the publication of the Table was commenced in the first volume of this JOURNAL, the calculations of wave-lengths in the extreme ultra-violet was not completed. These wave-lengths will be published in this and subsequent numbers of the JOURNAL.

[2] Strong line of iron at 2983.689. The strong *shaded* lines of iron and some other elements are with difficulty seen in the faint beginning of the ultra-violet solar spectrum, and as a consequence their intensities are much less than in corresponding metallic spectra.

[3] Violet portion of line partly due to a line of overlapping yellow.

[4] Red portion of line partly due to a line of overlapping yellow.

Wave-length	Substance	Intensity and Character	Wave-length	Substance	Intensity and Character
2992.693	Ni	0	3002.433		000
2992.828		0000	3002.593	Ni	00
2993.027		000	3002.743	Fe,-	00
2993.177		000	3003.102	-, Fe	0 N
2993.327		000	3003.182		1 N
2993.457		000	3003.312		000
2993.807		0000	3003.572		0 Nd?
2993.927		00	3003.773[1]	-, Ni	2 Nd?
2994.177	Cr	00	3003.962		00
2994.327		000 N	3004.230		00
2994.527 s	Fe, Ni	000	3004.572		000
2995.057 s	Ca	000	3004.732		1
2995.212	Cr, Co	00	3004.912		000 N
2995.347		000	3005.160 s	Cr	3
2995.597		00	3005.407 s	Fe?,-	3
2995.767[3]		00	3005.572		000 Nd?
2995.937		000	3005.852	-,Co?	2 d
2996.096		2	3006.059		0
2996.187		000	3006.262[2]		0 Nd?
2996.347		0000	3006.482		000 Nd?
2996.495	-, Fe?	2	3006.677		0 Nd?
2996.689	Co?, Cr	1	3006.982 s	Ca	0
2996.940		1	3007.237 s	-,Fe	1 N
2997.067		000	3007.405 s	Fe	1 Nd?
2997.317		00	3007.592		00 N
2997.437 s	Ca, Cu?	2	3007.757	Mn?	00
2997.602		000	3007.862		000
2997.787		00 N d?	3008.072		000
2998.066		0	3008.212 s	Fe	00
2998.266		00	3008.312	Mn?	00
2998.451		0	3008.582		00 N
2998.606		00	3008.744		0 Nd?
2998.776		000	3008.914		00
2998.916	Cr	2	3009.022		0000
2999.136		0000	3009.190	Fe?	1
2999.286		00	3009.302 s	-,Ca	1
2999.603 s	Fe,-	00 N	3009.462		00
2999.748 s	Ca	0	3009.642 s	-,Fe	2 N
2999.923		000	3009.822		1 N
3000.043		000	3010.277		0
3000.178		00	3010.522		00
3000.458		00	3010.731		0
3000.553	Fe,-	00	3011.257	Mn?	00 N
3000.693	Co,-	00	3011.390		00
3000.913	Ti?, Ca	000	3011.527		00
3001.103 s	Cr, Fe	00 Nd	3011.597	Fe	1 N
3001.373		00 Nd	3011.747		000
3001.763		000	3011.832		00
3002.093		000 N	3011.907		00 N
3002.288		000	3012.146[2]	Ni,-	5 d?

[1] Red portion of line partly due to a line of overlapping yellow.

[2] Violet portion of line partly due to a line of overlapping yellow.

[3] Very strong shaded iron lines.

Wave-length	Substance	Intensity and Character	Wave-length	Substance	Intensity and Character
3012.247		000 N	3020.936		000 N
3012.557 s		2	3021.170[2,3] s	Fe	3
3012.707		000	3021.346		000 N
3012.827		000 N	3021.516		0000 N
3013.037		0	3021.676	Cr	1
3013.169	Cr?	1	3021.821		0000 N
3013.227		0	3022.001		000 N
3013.437		00 Nd?	3022.216		0000Nd?
3013.691	Co	00	3022.371		00
3013.840	Cr	1	3022.476	Co	0
3014.067		000	3022.693		1
3014.215 s		0	3022.861	-,Mn	1
3014.282		1	3023.011		0000
3014.427		00	3023.178[2]		2 N
3014.552		000 N	3023.416		000
3014.752	Mn?	000	3023.559		00 N
3014.878		1	3023.796		000 N
3015.049	Cr	1	3023.984		0 Nd?
3015.300	Cr	2	3024.156 s	Fe,-	4 Nd?
3015.467		000	3024.326		000
3015.617		2	3024.465 s	Cr	4
3015.799	Co	000	3024.756		000 Nd?
3015.917		000	3024.908		1
3016.047	Fe?-	2	3025.095		1 Nd?
3016.300 s	Fe,-	4 Nd	3025.385 s		3
3016.557	Mn?	00	3025.571		0000 N
3016.622		000	3025.737	-,Fe?	2 N
3016.869		2	3025.961 s	Fe	2 N
3016.957		1	3026.131		00 N
3017.127		0000	3026.331		000 N
3017.308	Ti?	1	3026.486	Co	0
3017.361	Co?	0	3026.591	Fe,-	3
3017.516		0	3026.761		2
3017.691	Co, Cr	1 Nd?	3026.931		1
3017.786 s	Fe,-	1 N	3027.069		0
3017.961		00	3027.141		0
3018.086		000 N	3027.291 s	Fe	000 N
3018.248		1	3027.481		000 N
3018.361		00	3027.717		0
3018.601	Cr,-	2	3027.811		1
3018.919	Cr	1	3027.999		000 N
3019.078 s	-, Fe	1 N	3028.128[2]		3
3019.271	Ni	1 N	3028.243		1
3019.426		1	3028.403		00
3019.666		0000	3028.561		00 Nd?
3019.986		00 N	3028.716		0
3020.106		0 N	3028.806		0
3020.346		000 N	3028.980		1
3020.606[3] s	Fe	00 N	3029.134		1 Nd?
3020.826[3] s	Cr, Fe	00 Nd?	3029.261	Cr	1

[2] Violet portion of line partly due to a line of overlapping yellow.

[3] Very strong shaded iron lines.

Wave-length	Substance	Intensity and Character	Wave-length	Substance	Intensity and Character
3029.369	Fe?-	3	3037.510 s	Fe	10 N
3029.441		0 N	3037.685		0
3029.661		000	3037.895		0
3029.835	Ti?	4	3038.050	Ni	3
3029.936		000	3038.210		1
3030.091		1	3038.423	Co?,-	2
3030.261	Fe	3	3038.625		1
3030.356	Cr	2	3038.860		3
3030.591		000	3039.095		1
3030.720		1	3039.170		2
3030.881		000 N	3039.309		0000
3031.046		1	3039.433		2
3031.161		0	3039.660		0
3031.312	Fe	1	3039.721	Co,-	2
3031.454	Co, Cr	1	3039.883	Cr	2
3031.591	Cr?	00 N	3040.030		0000
3031.741	Fe	1	3040.130		000
3031.821		1	3040.340		0000
3031.975	-,Ni?	3	3040.435		1
3032.141		0000	3040.550	Fe	3
3032.336		000 N d?	3040.712	Mn	1
3032.567		1	3040.865		0
3032.741		0000	3040.950	Cr	2
3032.971		0000	3041.060		2
3033.026		3	3041.145		0
3033.211		2	3041.325	Mn?	00 N
3033.321		0000	3041.532		0 Nd?
3033.532		5	3041.740	Fe	2
3033.718		0	3041.867	Fe	2
3033.918		2	3042.005		00
3034.036		000	3042.150	Fe	3
3034.166		00	3042.365		0
3034.304	Cr	2	3042.592	Co	0
3034.558	Co,-	2	3042.765	Fe	3
3034.669		3	3042.957		0
3034.911		00	3043.239		0
3035.098		0	3043.456	Mn?	1
3035.341		0	3043.648		1
3035.468		1	3043.870	Mn?	0000
3035.581		000 N	3043.970		1
3035.847 s		5	3044.112 s	Co	3
3036.001		00	3044.220		000
3036.215	Ca?	0	3044.345		0
3036.370		00	3044.442		0000
3036.505		0	3044.671 s	Mn	3
3036.625		00	3045.100	-,Ni	3 } d
3036.880		1 Nd?	3045.183	Fe	4 }
3037.085		00	3045.440		000 N
3037.160	Cr	2	3045.560		0000 N
3037.330		1 N	3045.695	Mn,-	3

Wave-length	Substance	Intensity and Character	Wave-length	Substance	Intensity and Character
3045.870	-,Mn?	2 N	3053.856		1
3046.025		0000	3053.988	Cr	3
3046.150		0	3054.429	Mn, Ni	10
3046.375		00	3054.807	-,Co	1
3046.610		00	3054.931		0
3046.778 s	Ti,-	5	3055.051	Zr	0
3046.919		0	3055.233		0
3047.041		1	3055.374	Fe	4
3047.158	Mn	1	3055.428		2
3047.311		0	3055.563		0
3047.471		0 N	3055.701		0000
3047.725 s	Fe	20 N	3055.814 } s		2
3047.911		1 Nd?	3055.861 }		0
3048.151	,Co	0 Nd?	3056.021		0000 N
3048.327		1	3056.221		0
3048.449		000	3056.339		1
3048.563		3	3056.441		1
3048.701		000 Nd?	3056.691		0
3048.893		1	3056.861	Ti	2
3048.999	Mn, Co	2	3056.901		1
3049.124		0	3057.117		00 N
3049.261		00	3057.257		1
3049.462		3	3057.382		00
3049.649		2	3057.552 s	Ti, Fe	20
3049.856		000 N d	3057.753	Ni	2
3050.001		000 N	3057.907		1 N
3050.186 } s		2	3058.072		00
3050.231 }		4	3058.189	Ti	4
3050.374		0000	3058.457		1
3050.501		0000	3058.605		1
3050.623	Co	000	3058.812		0
3050.771		1	3059.012		1 N
3050.943	Ni	5	3059.212 s	Fe	20
3051.156		1	3059.377		0
3051.351		0000	3059.482		0
3051.528		2 N	3059.616		2
3051.721		000 N	3059.845	Ti	3
3051.896		00	3060.137	-,Co	1
3052.091		000 N	3060.192		00
3052.256		00	3060.337		00
3052.331	Cr?	0	3060.450		1
3052.396		0	3060.552		1
3052.591		1	3060.652	Fe?	1
3052.694		0	3060.727		1
3052.891		0	3060.878		2
3053.031		00	3061.093 s	Fe?	3
3053.173 s	Fe	4	3061.259 [1]		00 N
3053.341		000 N	3061.487	Zr	00 N
3053.530 s		7 d?	3061.682		0
3053.764		0	3061.772	Cr?	00

[1] Red portion of line partly due to a line of overlapping yellow.

Wave-length	Substance	Intensity and Character	Wave-length	Substance	Intensity and Character
3061.931 s	Co	3	3069.288		2
3062.082		00	3069.441		1
3062.222	Mn	1	3069.562		2
3062.358	Co,-	4 N	3069.788		1
3062.622		00	3070.022		1
3062.795		00	3070.145		0
3062.969		3d?	3070.372	Mn	3
3063.152		0000	3070.487		00
3063.282		1	3070.599		1
3063.348		3	3070.802		0
3063.512	Cu	000	3070.902		0
3063.612		2	3071.112		00
3063.662		3	3071.252		1
3063.836		2	3071.360	Ti	3
3063.912		00	3071.542		00
3064.043	Fe?	2	3071.662	-,Ba	00
3064.122		1	3071.784		0
3064.323		2	3071.905		00
3064.475	Co	1	3072.072	Co	1
3064.622		000	3072.222	Ti	3
3064.729	Ni	3	3072.289		0
3064.802		1	3072.435	Co	3
3064.936		1	3072.602		1
3065.062		1	3072.777		000
3065.201	Cr?,-	2	3073.091	Ti,-	6 Nd?
3065.423		1	3073.232	Mn,-	1
3065.602		0000	3073.342		2
3065.722		00	3073.477		0000
3065.882		0000 Nd?	3073.632	Co	00
3066.101	-,Mn	2	3073.784	Cr	1
3066.251		0	3073.939	Cu,-	0
3066.334	Ti	2	3074.104	Fe?	1
3066.471	Ti	1	3074.262	Fe?	2
3066.608	Ti, Fe?	2	3074.492		1
3066.793		000	3074.542	Fe?	2
3066.923		000	3074.803		0
3067.101	Fe?	1	3075.012		000 N
3067.230	Fe	2	3075.142		000
3067.369 s	Fe	8	3075.242		0
3067.493		1 N	3075.346 s	Ti	3
3067.764		1	3075.462		0
3067.895		1	3075.562		0000
3068.046		2	3075.702		0 N
3068.283	Fe	2	3075.840 s	Fe	3
3068.388		1	3076.002		1
3068.583		1	3076.105		1
3068.705		1	3076.372		0
3068.832		1	3076.542		1
3068.903		0	3076.692		0000
3069.053		00	3076.857		0

Wave-length	Substance	Intensity and Character	Wave-length	Substance	Intensity and Character
3076.938		0	3083.957		00
3077.134		0	3084.162		00
3077.295 s	Fe	3	3084.272		0000
3077.332 s		1	3084.397		000
3077.502		0000 Nd?	3084.562		0
3077.665		0	3084.682	Cr?	00
3077.747		1	3084.792		0000
3077.842	Fe?	0	3084.902		0000
3077.942	Cr	0	3085.004		1
3078.151 s	Fe?	4 d?	3085.150		0
3078.359		0	3085.313		2
3078.494		2	3085.438	Fe?	1
3078.552	Fe	3	3085.502		1
3078.769 s	Ti,-	8 d?	3085.652		0000
3078.932		000	3085.780		1
3079.022		00	3085.827		1
3079.212		000 Nd?	3085.972		000
3079.415		00	3086.102		000 N
3079.482	Co	0 N	3086.217		000
3079.724 s	Mn	2	3086.335		0
3079.862		0000	3086.503	Co	1
3079.932		000	3086.636		2
3080.086	Fe?	4	3086.742		00
3080.223	Fe?	1	3086.893 s	Co	4
3080.352		0	3087.094		000
3080.475		1	3087.182 s	Ti	1
3080.529		00	3087.451		1
3080.702		00	3087.559		0
3080.864 s	-,Ni	5	3087.639	Cr?	000
3080.984	Cd	00	3087.799		00
3081.112		1	3087.949	Co	0 Nd?
5081.354		2	3088.145 s	Ti	7 d?
3081.419	Mn,-	3	3088.294		0 N
3081.567		0	3088.461		1
3081.657		1	3088.716		00
3081.787		1	3088.858		2
3081.832		1	3088.929		0000
3081.947		0	3089.106		0
3082.142	Mn?	1	3089.202		000
3082.275 s	Al	5	3089.509	Ti	1
3082.632		00	3089.614		00
3082.734	Co	2	3089.719	Co	3
3082.957	Co	00 N	3089.851		2
3083.149		1	3089.974		2
3083.275		1	3090.328	Ti?, Fe?, Co	1 N
3083.389		1	3090.480		1
3083.489		00	3090.592		0
3083.610		0	2090.839		00
3083.727		00	3090.974		0
3083.859 s	Fe	4	3091.177	-,Mg	4

Wave-length	Substance	Intensity and Character	Wave-length	Substance	Intensity and Character
3091.319		1 N	3097.935		000
3091.477		1	3098.070		000
3091.689	Fe	4	3098.177		0
3091.799		00	3098.298	Fe, Co	2
3091.976		0	3098.430		0000
3092.199		0	3098.560		000
3092.339		0000	3098.693		2
3092.509		1	3098.825		000
3092.579		00	3098.930		00
3092.704		0000	3099.073		00
3092.818 s	Al	4	3099.220	Ni,-	2
3092.957 s	Al	1	3099.340	Zr	0
3093.089	Mg	1	3099.523		1
3093.229		2 N	3099.680		0 N
3093.452	Fe	1	3099.780	Co	000
3093.604		0	3099.895		000
3093.714		00	3100.001 } s	Fe	3
3093.829		000	3100.092 }	Fe	3
3093.929	Fe	1	3100.255		00 N
3093.989		1	3100.430 s	Fe, Mn	4 N
3094.049	Fe, Cu?	000	3100.629		000
3094.174		0000	3100.787 s	Fe, Ti	3
3094.311		1	3100.944	Fe, Co?	1
3094.401		1	3101.047		0
3094.470		00	3101.117	Fe	1
3094.575		00	3101.347		1
3094.732 s		2	3101.522		00 N
3094.830		0000	3101.679 s	Ni	4 N
3095.003 s	Fe?,-	4	3101.799		00 N
3095.190		0	3102.000 s	Ni	3
3095.360	Fe	2	3102.079		00 N
3095.453		3	3102.253		1
3095.660		00 N	3102.404	V	3
3095.830	Co	00 Nd?	3102.474	-,Co	2
3095.990	Cr,-	0	3102.624		0000
3096.145		1	3102.748		0
3096.244		2	3102.869		00
3096.430		0	3102.987	Fe	1
3096.510	Co	0	3103.084		0
3096.655	Cr?	000	3103.214		0000Nd?
3096.730		0	3103.389		0
3096.870	Co,-	000 N	3103.454		1
3097.008	,-Mg	5	3103.599		00
3097.235	Ni	2	3103.719		0000
3097.282	Ti	1	3103.886	Co, Fe?	2
3097.460		000	3103.924	Ti, Fe?	3
3097.538		00	3104.087	-,Co	00
3097.595		00	3104.269		0
3097.723		00	3104.379		0000
3097.890		1	3104.454		00

Wave-length	Substance	Intensity and Character	Wave-length	Substance	Intensity and Character
3104.676		2 N	3112.183	Fe, Ti?	2
3104.819		00	3112.320		1 N
3104.884		0000	3112.575	Ti?	00
3105.019		00	3112.715		0000
3105.199	Ti	2	3112.790		00
3105.279		1	3112.910		0000
3105.429		0000	3113.060		00
3105.569	-,Ni	2	3113.203		00
3105.668		1	3113.320		0000
3105.782		1	3113.490		1
3105.999	Co?	0000 N	3113.560	Co	0
3106.137		2	3113.698	Fe?	1
3106.346	Ti	3	3113.773		0
3106.664 s	Zr	2	3113.945		0 N
3106.914	Ti	000	3114.185	Ti?	1
3107.012		1	3114.232	-,Ni	3
3107.197	Co,-	00 N	3114.423		2
3107.427		0	3114.460		1
3107.564		0	3114.590		0000
3107.670		1	3114.735		00
3107.830	Ni?	0	3114.780		0
3107.959		00	3114.885		1
3108.089	Fe?	1	3115.150 s	Fe	1 N
3108.239		0000 N	3115.390		0
3108.369		00 N	3115.460		0
3108.469		0000	3115.575		0
3108.661	Cu?	00	3115.670		00
3108.787		0	3115.775		1
3108.991		0	3115.990		0
3109.057		1	3116.160		0000 N
3109.179		1	3116.370	Fe?	1
3109.439 s	-,Cr	3	3116.500		0
3109.609	Co	00	3116.610	Fe?	1
3109.729		1	3116.741	Fe	2
3109.909		0000	3116.835		1
3110.034		00	3117.025		0
3110.190	Co,-	1	3117.090		1
3110.351	Fe?	5 Nd?	3117.145		00
3110.635		00	3117.309		1
3110.810	Ti, V	5 Nd?	3117.357		0
3110.955	Co, Fe?	2	3117.540	Ti?	00 N
3111.000	Cr, Zr	1	3117.770	Ti, Fe?	2
3111.180		0000	3117.877		1
3111.285		00	3117.998		2
3111.410	Co?	00 N	3118.249	Ti?	1
3111.530		0000	3118.360	Co	0
3111.640		0000	3118.498	V	3
3111.791	Fe?	1	3118.665		00
3111.920	Fe?	2	3118.764	Cr,-	2
3112.050		00	3118.935		0

Wave-length	Substance	Intensity and Character	Wave-length	Substance	Intensity and Character
3119.144		00	3126.319	V, Fe	5
3119.307	-,Cr	1 Nd?	3126.444		000
3119.460		00	3126.584		00
3119.613	Fe	3	3126.729		1
3119.787	Ti?, Cr	1	3126.879	Co,-	1
3119.911	Ti	1	3126.959		0
3120.121		00 N	3127.159		00
3120.201		0000	3127.229		000
3120.346		1	3127.359	Fe?, Co	0
3120.481	-,Cr	3	3127.474		0
3120.539	Fe	2	3127.604		0
3120.711		000	3127.784		2 d?
3120.841	Zr	0	3127.959		1
3120.986	Fe?	1	3128.199		0 N
3121.191		0000	3128.402		1
3121.270 s	V	4	3128.499		0
3121.529	Co	1	3128.634		0
3121.714	Co,-	3	3128.819	Cr,-	2
3121.893		1	3128.889		00
3121.969		00	3129.010	Fe?	1
3122.079		00	3129.120	Co	000
3122.192		0	3129.220	Fe?	1
3122.329		0	3129.290	Zr	0
3122.427	Fe?	1	3129.433	Fe, Ni	3
3122.680		2	3129.645	Co,-	00 N
3122.774		00	3129.880 s	Zr	0
3122.894		0000	3130.060		00 N
3123.019		0	3130.250		00 N
3123.059		00	3130.380	V	3
3123.203	Ti	0	3130.529		1
3123.371		00	3130.681		1
3123.460	Fe?	0	3130.745	Be?	0
3123.554		00	3130.909	Ti,-	3
3123.672		1	3131.169	Be?	1 N
3123.809		0000	3131.350	Cr,-	0
3123.889	Ti?	00 N	3131.475		0
3124.070		1	3131.560		0
3124.208	Fe?	0	3131.640		0
3124.394		000 N	3131.822		0
3124.599		00	3131.920		000
3124.749		00	3132.065		000
3124.799		000	3132.169	-,Cr	4
3124.914		00	3132.303	-,Co	0
3125.029		2	3132.402	Mn?	0
3125.109	Cr,-	4	3132.635	Fe?	2
3125.164		2	3132.749	Mo	1
3125.309		5	3132.935	Cr,-	00 N
3125.579	Cr?	00	3133.180		1
3125.779	Fe, V	5	3133.330	Cd, Zr	1
3126.029	Zr	0	3133.449	V	2

RESEARCHES ON THE ARC SPECTRA OF THE METALS. II. THE SPECTRUM OF TITANIUM.[1]

By B. HASSELBERG.

1. FOR some time past I have been engaged at the Physical Institute of this place in a systematic investigation of the arc spectra of the metals, and in recent publications of the Academy[2] I have described at some length the spectrum of chromium. The investigation includes that part of the spectrum which can be photographed with glass objectives, and which extends from λ 3450 to D. The following pages are devoted to a consideration of the same part of the spectrum of Titanium. But while chromium has only scattered unimportant lines in the less refrangible parts of the spectrum, titanium has a considerable number of very characteristic groups in the same region, and it would have been desirable to include these groups in the investigation, if such a course had been possible. As it was, the considerable difficulties which are still in the way of obtaining satisfactory photographs in this part of the spectrum, have induced me to forego this part of the investigation for the present, particularly since, on the one hand, the main requirements of astrophysics are satisfied by the part which is here considered, and, on the other hand, it is probable that the less refrangible rays can be photographed under considerably improved conditions in the immediate future.

2. Our present knowledge of the spectral relations of titanium rests almost exclusively on the investigations carried out by Thalén[3] nearly thirty years ago. At first, in these investigations, titanic acid was used, with which only a small number of excessively fine and inconstant lines could be observed in the spark

[1] "Untersuchungen über die Spectra der Metalle im electrischen Flammenbogen, II., Spectrum des Titans." Translated from the *Kongl. Svenska Vetenskaps-Akademiens Handlingar*, **28**, No. 1, Stockholm, 1895.

[2] *Svenska Vetensk. Akad. Hand.*, **26**, No. 5, 1894.

[3] *Nova Acta Reg. Soc. Sc. Upsal.*, Ser. III., **6**, 1868.

spectrum and identified with solar lines. These lines were found later in the electric arc, when carbon points which had been saturated with calcium chloride were employed, and in order to determine their origin, the titanium spectrum was again produced, with the aid of titanium chloride. This spectrum proved to be free from calcium lines, and contained, among a great multitude of sharp lines, the lines which had formerly been observed, and which it was consequently necessary to ascribe to titanium. At the same time the result was established, that the presence in the calcium spectrum of the lines in question was due to titanium in the carbon points.

The number of lines observed by Thalén in this spectrum between λ 4163 and λ 6556 is about 200, of which the greater part occur as absorption lines in the solar spectrum. The conclusion that titanium exists in the atmosphere of the Sun is therefore perfectly well established, although the intensities of corresponding lines are not always the same; this relation is one that is constantly met with, even in the case of metals, which, like iron, have an undoubted part in the Sun's chemical constitution. It will moreover appear in the following pages that many lines which were noted as "broad" by Thalén, are really groups of two or more lines, each component having a corresponding line in the solar spectrum; thus, the existence of the metal in the Sun receives a still further confirmation.

3. Since, according to Thalén's experience, titanic acid in its ordinary form is unsuitable for producing the spectrum by means of the induction spark, it is probable that this will also be the case when the electric arc is employed. The use of salts is also objectionable in many respects, and at first, therefore, I tried to use the pure metal in the form of powder; but this method likewise proved to be impracticable, since, when the current was passed, the burning metal was scattered in all directions and the spectrum was quickly extinguished. Titanic acid was then obtained from Baron Nordenskiöld in the form of *rutile*, and with this mineral perfectly satisfactory results were obtained. A small piece introduced into the crater of the positive (lower) carbon,

immediately melts into a bead, above which the arc burns very quietly, giving a brilliant, steady and lasting spectrum. It is true that iron in considerable quantities is to be feared as an impurity, but so far as I have been able to observe, the material which I have used merely increases, by a scarcely perceptible amount, the number and intensity of the iron lines which are due to the carbon points, and which would be visible in any case.

4. After the production of a titanium spectrum which could be maintained for any desired length of time had been made possible, the photographic work could be taken up. With regard to the instrumental appliances and the photographic methods which were used, I have little of importance to add to the account given in my previous memoir. Everything remained as before except that, in some cases, Ilford color-sensitive plates were used instead of those of Lumière, for the reason that the last lot of Lumière plates was considerably inferior to the first with respect to fineness of grain. The Ilford plates were notably better in this respect, although they did not yield quite so brilliant negatives.

5. The photographs were measured in the same way as those of the chromium spectrum. First a provisional catalogue was made, containing all the lines to be measured, and by comparison with photographs of the iron spectrum taken at the same time, most of the iron lines in the titanium spectrum were at once excluded. The measurements were then carried out in two independent series, each on different plates, and the definitive wave-lengths were determined from them according to well-known methods. For measuring I used the same dividing engine by Perraux, as before; but since the old microscope belonging to it was in many respects not all that could be wished, it was replaced by a new one, furnished by Toepfer, of Potsdam, which had Zeiss lenses, and which proved to be entirely satisfactory. It is characterized by great sharpness and clearness of the image to the extreme edge of the very large field, so that my photographs, which even formerly appeared to

be good, now represented for the first time the high perfection of the spectra yielded by the Rowland grating. It frequently happened that a close double line was resolved by the new microscope, which appeared single under the old one. Further, the eyepiece can be accurately focused on the cross-wires by means of an oblique slot in its mounting, and the cross-wires can be rotated about the axis of the instrument, so as greatly to facilitate the adjustment of the wire to parallelism with the spectral lines. The magnifying power can be varied within the limits of 10 and 18 diameters.

In consequence of the greater sharpness of the image, the certainty of a setting on the spectral lines is perceptibly increased. It is therefore not improbable that two settings on each line would be a sufficient number in measuring each plate, instead of three as in earlier measures, and that the accuracy would not be sensibly diminished by the change. However, I have not made any change as yet, in order to preserve the homogeneity of the measurements.

6. Although a few words have sufficed for the points of the investigation hitherto touched upon, the question of the elimination of lines due to impurities requires a more detailed consideration. This is by far the most difficult part of the investigation, and no surprise need be felt if the desired end has been only approximately reached. Nevertheless, I entertain the hope that the impurities which remain are of only secondary importance.

The adopted method of elimination has already been described in connection with the spectrum of chromium. As soon as the wave-length catalogue of titanium was completed, it was compared line by line with the corresponding definitive or provisional catalogues of iron, cobalt, nickel, chromium and manganese. All pairs of lines in these metals and titanium which differed by less than 0.10 tenth-meter were carefully studied on plates containing both spectra which were prepared specially for the purpose, in order to obtain a definitive judgment as to their coincidence or non-coincidence, and, in the former case, to determine the probable origin of the foreign line from a

consideration of the relative intensities. For calcium and other metals investigated by Kayser and Runge, I used the catalogues of these authors in the manner already described, but hitherto without a direct comparison of the spectra. I have then regarded the lines as follows:

A. As belonging to *titanium:*

a All lines which are distinctly separated from neighboring lines of the comparison metal.

b Those lines which coincide with lines of the comparison metal, but which have a much greater intensity in the titanium spectrum.

c Those lines which exactly coincide and are strong in both spectra, so that they must be regarded as belonging to both metals.

B. As *doubtful*, lines which perfectly coincide, but which are of feeble intensity in both spectra, and which may therefore be supposed to have their origin in a third substance existing as an impurity in the two metals compared.

C. As lines due to *impurities*, and therefore to be stricken from the titanium spectrum, such lines as are weak in the titanium spectrum and strong in that of the comparison metal, although coincident in both spectra.

Proceeding from these principles, I have arrived at the following results of the comparisons:

I. TITANIUM AND IRON.

As already mentioned, most of the iron lines, or at any rate all of the most conspicuous ones, were eliminated in the first review of the spectrum. A comparison which was made after the completion of the definitive catalogue with the iron spectrum of Kayser and Runge revealed a considerable number of cases in which lines of the two spectra had so nearly identical positions, that a new comparison on special plates containing both spectra seemed to be necessary. In order to make these and similar comparisons without an excessive amount of labor, a drawing of at least one of the spectra was necessary and for this purpose the originals of the accompanying plates were used. The results are given in the following table:

Ti λ	Ti i	Fe λ	Fe i	Remarks
3493.42	1.2	93.44	1	Fe missing.
3505.01	3	05.02	1.2	Coincident.
20.16	1.2	20.21	1	Fe missing.
24.37	2.3	24.41	1.2	Coincident.
26.18	1.2	26.15	1.2	Probably belongs to Fe, as the iron line on the comparison plate is strong.
30.53	3	30.55	1.2	Coincident. Impurity due to Ti in Fe, Ni, Co.
58.66	2	58.69	4	Coincident. The Ti line considerably stronger than other lines in the vicinity corresponding with strong iron lines.
78.84	2	78.87	1.2	Coincident. } The lines in Ti spectrum are certainly
93.62	2	93.69	1	Fe missing. } Cr lines.
96.18	2.3	96.10	1	Divided.
98.84	2.3	98.92	1	Divided.
99.25	2.3	99.19	1	Coincident? Fe line probably divided from Ti, Ni.
3603.98	1.2	04.05	1	Fe barely visible.
04.39	1.2	04.36	1	Fe missing.
06.16	1.2	06.12	1	Fe missing.
14.35	2	14.33	1	Divided. λ Fe < λ Ti.
19.61	1.2	19.61	1	Ni, Co has a strong line (5 and 4). To be stricken from Fe and Ti.
21.35	2	21.31	1	Divided. λ Fe < λ Ti.
24.96	2	25.02	1	Coinc.? Perhaps λ Fe > λ Ti. Probably we have { 24.90 Ni−3 ; 24.96 Ti−2 ; 25.02 Fe−1
38.10	2	38.05	1	Divided; *i* for Fe > 1.
58.22	3.4	58.14	1	Divided.
69.08	2.3	69.11	1	Coincidence probable.
71.81	3	71.87	1	Divided. λ Fe > λ Ti. Fe line extremely faint.
77.89	1	77.83	2.3	Divided.
81.38	1.2	81.42	1	Divided. Ti appears to lie between two faint Fe lines.
83.19	1.2	83.25	1	Hard to see; probably divided, otherwise impurity due to Co.
90.03	3	90.05	1	Coincident.
3708.82	1.2	08.79	1	Both missing from comparison spectrum.
21.75	2	21.76	1.2	Divided; λ Ti > λ Fe.
59.42	3.4	59.37	1	Fe missing.
82.26	1.2	82.30	1	}
3801.25	1.2	01.22	1.2	} Too faint for observation.
06.19	1	06.19	1	}
27.80	1.2	27.79	1.2	Possibly divided.
29.85	1.2	29.93	1.2	Both faint; suspected λ Fe > λ Ti.
46.56	2.3	46.62	1.2	Probably divided, but apparently λ Fe < λ Ti.
48.48	1.2	48.49	1	Probably divided; λ Fe < λ Ti.
55.99	1.2	56.07	1	Probably divided; λ Fe > λ Ti.
69.75	1.2	69.76	2.3	Coincident. Rather strong Fe lines in the vicinity missing from Ti spectrum.
74.32	2	74.25	1	Divided; λ Fe < λ Ti.
90.11	2	90.09	1	Divided; λ Fe < λ Ti; Fe weak.
3900.68	2.3	00.71	1.2	Coincident; *i* for Fe > 1.2.
58.33	3.4	58.36	1	Also in Ni. Impurity in Fe and Ni due to Ti.

Ti λ	Ti i	Fe λ	Fe i	Remarks
3981.92	3.4	81.94	3.4	Perfect coincidence; not divided.
98.77	4	98.83	1	Fe missing.
4009.05	3	09.04	1	Coinc.? Fe line much stronger than here indicated.
53.97	1.2	53.94	1	Perhaps divided, and λ Fe < λ Ti.
55.19	2.3	55.19	1.2	Divided, but excessively close. Intensity of the Fe line 1.2.
59.07	2	59.06	1	Coincident. Fe stronger than given by K. and R. Also weak Ni line.
82.57	2.3	82.62	1.2	Coincident. Fe faint.
99.94	1.2	99.94	1.2	Fe missing.
4105.31	1.2	05.31	1.2	
09.92	1.2	09.95	4	Fe a little more refrangible than Ti.
11.91	2.3	11.92	1.2	Like the preceding.
29.30	1.2	29.35	1	?
34.60	1.2	34.57	1.2	Divided; λ Ti < λ Fe.
43.99	2.3	44.03	5	Belongs to Fe.
61.67	1	61.64	1.2	Divided; λ Fe < λ Ti.
63.80	2.3	63.81	1.2	Perhaps divided, and λ Fe > λ Ti.
72.04	2	72.06	1	Coincident. Fe distinct but faint.
73.66	1.2	73.59	1	Fe distinct; divided from Ti; λ Fe < λ Ti.
74.61	1.2	74.54	1	Fe missing.
86.27	3.4	86.27	1	
4265.42	1.2	65.44	1.2	Fe weak. Coinc.?
78.34	2	78.42	1.2	Trace of Fe; coinc.?
88.29	1.2	88.32	2.3	Complete coincidence.
90.07	1.2	90.11	1	Fe missing.
91.07	3	91.06	1	Perhaps divided, and λ Fe < λ Ti.
95.91	3.4	95.90	1	Fe absent
4301.23	3.4	01.23	1	Also in Co, therefore impurity in Co and Fe due to Ti.
14.50	2.3	14.50	1	Fe absent
18.83	3.4	18.85	1	Fe absent
25.30	3	25.26	1	Fe absent
38.05	3	38.12	1	Fe absent K. and R. give for Ca 18.80.
46.76	1	46.73	2.3	Divided; λ Fe < λ Ti. Intensity of Fe line < 2.3.
67.81	1.2	67.75	1	Distinctly divided; λ Fe < λ Ti. Intensity of the Fe line > 1.
79.40	2	79.43	1.2	Fe missing; also a weak line in Co.
84.85	2	84.89	1.2	Probably divided; λ Fe > λ Ti.
88.69	1	88.64	3.4	Distinctly divided; λ Fe < λ Ti.
90.11	2	90.17	1.2	Fe missing.
4400.74	1.2	00.79	1	Fe line doubtful, on account of ghost of strong Fe line λ 4404.94.
07.83	1.2	07.87	3.4	Distinctly divided; λ Fe > λ Ti. Δλ > 0.04.
08.70	1.2	08.61	3.4	Widely divided. Intensity of Fe line too great.
11.26	1	11.19	1	?
18.52	1.2	18.50	1	Fe missing.
26.24	2.3	26.15	1	
31.46	2	31.50	1	Fe weak; λ Fe > λ Ti.
32.76	1.2	32.75	1.2	Fe visible; coinc.?
41.86	1.2	41.87	1	Fe missing.
62.26	1.2	62.18	2.3	Fe quite strong. Fully divided.

Ti λ	Ti i	Fe λ	Fe i	Remarks
4463.70	2	63.73	1	Fe missing.
65.96	2.3	66.02	1	Fe distinct; possibly λ Fe < λ Ti. Also a line in Co. Both probably impurities due to Ti.
71.40	2.3	71.38	1	Fe missing.
75.00	2.3	74.94	1	Traces of Fe; suspected λ Fe < λ Ti.
79.86	2	79.80	1.2	Fe distinct; lines divided. λ Fe < λ Ti.
96.33	3	96.27	1.2	Fe weak; lines divided. λ Fe < λ Ti.
97.90	1.2	97.93	1	Fe missing.
4527.48	3	27.42	1	Traces of Fe; apparently λ Fe < λ Ti.
33.42	3.4	33.42	1	Fe distinct. Exact coincidence. The line coincides with a ghost of the strong Fe line 31.31, and like the corresponding line in Ni is an impurity due to Ti.
34.15	2.3	34.20	1	Co has 34.18 (4) and is probably divided from Ti.
34.97	3.4	35.01	1	Fe missing. The lines in Fe and Ni are impurities due to Ti.
35.75	3	35.72	1	
36.12	3	36.17	1	Fe missing.
36.25	3			
48.93	3.4	48.95	1	
58.28	1.2	58.25	1	Trace of Fe; coincidence?
94.28	1	94.32	1	Fe missing. Ti weak.
4629.47	2.3	29.51	1	Coinc.? Traces of Fe. The line in Fe belongs to Co.
40.60	1	40.51	1	Fe missing.
75.27	2.3	75.30	1	
4792.65	2.3	92.69	1	
4811.24	2	11.29	1	
44.13	1.2	44.20	1	Fe missing, or only as a trace.
48.62	2	48.64	1	Fe missing.
70.28	3	70.21	1	Trace of Fe; probably divided, and λ Fe < λ Ti.
4913.76	3	13.86	1	Fe missing.
48.40	1.2	48.45	1	
77.92	1.2	77.86	1	
5025.72	3	25.67	1	
87.24	2.3	87.23	1	
5103.39	1	03.44	1	Missing on several plates of both Ti and Fe.
73.94	3	73.92	1	Fe missing.
93.15	3	93.17	1	
94.26	1.2	94.27	1	
5201.32	1.2	01.29	1	
19.88	2	19.83	1	
24.46	2.3	24.47	1	
26.70	1.2	26.70	1	
84.61	1.2	84.70	1	
5409.81	2.3	09.82	1	
38.53	1.2	38.58	1	Fe missing. Ti weak.
72.90	1.2	72.95	1.2	Fe missing.
81.64	2.3	81.69	2.3	Traces of Fe. Coinc.? Mn has a strong line here.
5514.78	3	14.78	1	Fe missing.
5712.07	2	12.09	1.2	Traces of Fe. Coinc.? Line probably belongs to Ni and Ti.
15.30	2.3	15.31	2.3	Traces of Fe; perhaps λ Fe < λ Ti. Line probably belongs to Ti and Ni.
40.20	2	40.17	1	Fe missing.

It will be seen from this table, in which, to facilitate the comparisons, I have given the intensities of Kayser and Runge reduced to my own scale, that a considerable number of the faintest iron lines observed by these investigators were not found by me, and this was also the case in the spectrum of chromium. The explanation of this circumstance would seem to lie in the greater purity of the iron which I used, provided that the absence of the lines is not due to my possible use of two weak a current. In the latter case—if the lines appear with a stronger current and have exactly the same positions as the titanium lines,—they would generally (taking their intensities into account) have to be excluded from the spectrum of iron, as impurities due to the presence of titanium.

In the group *A*, *c* containing lines which belong to both metals, are to be placed the following lines.

λ	i	
	Ti	Fe
3558.66	2	4
3869.75	1.2	2.3
3981.92	3.4	3.4
4288.29	1.2	2.3
5481.64	2.3	2.3

The last of these lines is found in my spectrum of iron as a trace only. On the other hand manganese has a strong line here ($i=3$), and for this reason the line observed by Kayser and Runge may be regarded as due to maganese existing in iron as an impurity.

In group *B* fall the following lines, which I provisionally ascribe to titanium, since it cannot be decided at present whether they belong to a third metal or not:

λ	i	
	Ti	Fe
3526.18	1.2	1.2
3708.82	1.2	1
3782.26	1.2	1
3801.25	1.2	1.2
3806.19	1	1
4109.92	1.2	4
4129.30	1.2	1
4265.42	1.2	1.2
4411.26	1	1
4433.76	1.2	1.2
4594.28	1	1
5103.39	1	1

The intensity of the line λ 4109.92 is certainly estimated too high by Kayser and Runge; I find it to be only 1.2.

As impurities only the following lines remain to be considered, after the exclusion of lines from the titanium spectrum on the first revision:

λ	i		
	Ti	Fe	
3578.84	2	1.2	Cr
3593.62	2	1	Cr
3619.61	1.2	1	Co, Ni
3683.20	1.2	1	Co
4143.99	2.3	5	

Of these lines only the last is an iron line. The others belong neither to titanium nor to iron, but to cobalt, nickel and chromium, and are therefore to be removed from the iron spectrum of Kayser and Runge, as impurities.

2. TITANIUM AND COBALT.

The result of the comparison was the following table of approximate coincidences:

Ti λ	Ti i	Co λ	Co i	Remarks
3495.88	2	95.81	3.4	Divided; λ Ti > λ Co.
3530.53	3	30.52	1.2	Coincident.
42.69	1.2	42.73	1	Coincidence impossible to decide upon.
87.27	2	87.30	5	Coincident. To be stricken from the Ti spectrum.
99.25	2.3	99.27	2	Coincident.
3605.46	2	05.49	3	Coinc. The line in Ti spectrum belongs to Cr. The Co line must, however, be independent of Cr, since the two Cr lines at λ 3593.57 and λ 3578.81 are missing from the Co spectrum.
09.45	1.2	09.46	1.2	
13.89	2	13.90	1.2	Coinc. The Ti line variable.
19.61	1.2	19.54	4	Coinc. probable.
33.60	2	33.51	1.2	Widely separated.
62.37	2.2	62.33	3	Divided; λ Ti > λ Co.
83.20	1.2	83.18	3.4	Variable in Ti.
3702.42	2	02.40	2.3	Divided; λ Ti > λ Co.
07.68	1.2	07.61	2	Widely separated.
3860.61	1.2	60.56	2	Probably divided.
61.25	1.2	61.30	3	Divided; λ Co > λ Ti.
90.12	1.2	90.16	1.2	Coinc.? Perhaps λ Co > λ Ti.
98.68	2	98.64	2	Co line doubtful.
3904.95	3.4	04.93	1.2	Coinc.
36.11	1	36.12	4	Coinc. To be stricken from the Ti spectrum.
4109.92	1.2	09.83	1.2	Co barely visible; probably belongs to Fe.
4287.55	3.4	87.51	2	Coincidence apparently exact.
4301.23	3.4	01.22	1.2	Exactly coincident. Co line weak. Also in Fe (1).
75.61	1.2	75.70	2.3	Widely separated.
79.40	2	79.37	1.2	Divided. Also in Fe.
95.99	1.2	95.99	2	Divided, but slightly.
4416.70	2	16.63	1.2	Distinctly separated.
17.88	2.3	17.88	1	Co line barely visible.
62.26	1.2	62.17	1.2	Widely separated. The line in Co belongs to Fe.
65.96	2.3	65.95	1.2	Co line variable. Also a weak line in Fe.
4534.15	2.3	34.18	4	Probably divided.
49.79	3	49.80	4	Divided, but excessively close.
52.62	3.4	52.60	2	Coincidence exact; *i* for Co appears to be variable.
4623.24	3	23.15	2.3	Widely separated.
29.47	2.3	29.47	4.5	Coincidence apparently exact; possibly λ Ti < λ Co.
45.36	2.3	45.34	1.2	Co line variable.
97.10	2	97.19	1.2	Widely divided.
4766.48	2	66.57	2	Widely separated.
71.26	1.2	71.27	3.4	Exactly coincident.
78.44	2.3	78.42	2.3	Perhaps divided; λ Ti > λ Co.
80.15	1.2	80.14	4	Coinc.
4928.50	2.3	28.48	3	Absolute coincidence.
81.92	4	81.91	1	Co extremely faint. To be stricken from the Co spectrum.
5001.16	2.3	01.15	1	Co missing.
07.42	4	07.48	1.2	Divided; λ Co > λ Ti.
13.45	3	13.46	1	Co missing.
5283.63	2.3	83.68	1.2	Probably divided; λ Ti < λ Co.
5369.81	2.3	69.78	3	Coincident; *i* variable in Ti spectrum.
5488.44	2.3	88.37	1.2	Divided; λ Co < λ Ti.

It will be seen that in most of these pairs the lines are independent of each other. I believe that the following lines may with some probability be regarded as belonging to both metals:

λ	i	
	Ti	Co
4629.47	2.3	4.5
4928.50	2.3	3
5369.81	2.3	3

Of these lines the first is (according to Rowland also, who gives the wave-length 4629.51), to be ascribed to both titanium and cobalt. The lines which I regard as doubtful are:

λ	i	
	Ti	Co
3609.45	1.2	1.2
3613.89	2	1.2

On the other hand the following lines are to be removed from the titanium spectrum, as impurities due to cobalt:

λ	i	
	Ti	Co
3587.27	2	5
3619.61	1.2	4
3683.20	1.2	3.4
3936.11	1	4
4771.26	1.2	3.4
4780.15	1.2	4

The line λ 3683.20 is ascribed by Rowland (with wave-length 3683.21) to iron and vanadium as well as to cobalt.

3. TITANIUM AND NICKEL.

The following table contains the results of the comparisons of these two spectra:

Ti λ	Ti i	Ni λ	Ni i	Remarks
3495.88	2	95.80	1	The line in Ni is the Co line 95.81 (3.4); divided from Ti.
3530.53	3	30.45	2	Coinc. Co has a line at 30.52 (1.2). Probably belongs to Ti.
87.27	2	87.35	1.2	The line in Ni belongs to Co (87.30, $i = 5$). To be stricken from Ti.
99.25	2.3	99.25	2	Coincident.
3609.45	1.2	09.45	2.3	Ti line variable. Extremely faint on comparison plate; therefore to be stricken out.
13.89	2	13.90	1.2	The Ni line probably a ghost, and therefore to be stricken out.
19.61	1.2	19.60	5	Probable coincidence either with Ni or with Co 19.54. To be stricken from the Ti spectrum.
24.97	2	24.90	3	Widely separated; λ Ti > λ Ni.
36.05	1	35.95	1.2	Ni missing from comparison plate.
97.05	1	97.00	1	Coincident.
3722.70	2.3	22.70	3	Perhaps slightly divided, in sense λ Ti > λ Ni.
3811.56	1.2	11.45	1	Widely separated; λ Ti > λ Ni.
61.25	2	61.30	1	Divided; λ Ti < λ Ni.
3936.11	1	36.10	2.3	To be stricken from Ti; probably belongs to Co.
58.33	3.4	58.35	1	Exact coincidence. These lines are probably to be stricken from the Ni spectrum. The line 81.91 belongs to Ti and Fe.
81.91	3.4	81.95	1	
89.92	4	89.90	1	
98.77	4	98.75	1.2	
4025.26	1	25.25	1.2	Ni line so faint that coincidence could not be decided upon.
58.28	2	58.35	1	Like the above.
59.07	2	59.05	1	Like the above.
64.36	2	64.45	2	Widely divided.
4164.80	1	64.85	1	Coinc. Common impurity?
4318.83	3.4	18.85	1	Ni missing; K. and R. give for Ca 18.80.
30.85	1.2	30.84	2	Perhaps divided.
41.51	1.2	41.57	1	Ni missing.
4455.48	3	55.50	1	Ni missing.
63.70	2	63.60	2	Widely separated. The Ni line lies between Ti 63.70 and 63.52 and is divided from both.
80.72	2	80.80	2	Coinc. Ni weak on comparison plate.
81.41	2.3	81.35	1	Ni missing.
4506.51	1.2	06.50	1	Ni missing.
33.42	3.4	33.40	1	Ni missing. K. and R. have for Fe 33.42, weak. Ti line certain.
34.15	2.3	34.20	1	The line in Ni spectrum belongs to Co, and is probably divided from Ti.
34.97	3.4	35.00	1	Ni missing from comparison plate.
49.79	3	49.85	1	The line in Ni spectrum belongs to Co, and is divided from Ti.
60.08	2	60.10	2	Coinc. Ni line variable.
4629.47	2.3	29.50	1	The line in Ni spectrum belongs to Co.
55.82	2	55.87	1.2	Division uncertain; common impurity?
4799.95	2.3	4800.00	1	Coinc.
4864.37	1.2	64.46	1	Divided; λ Ti < λ Ni.
5014.40	4	14.40	1	Coinc.
5397.28	2	97.30	1	Divided; λ Ti < λ Ni.
5712.07	2	12.05	3	Coinc.
15.30	2.3	15.30	3	Perhaps slightly divided.

Only the following four lines are to be regarded as belonging to group *A, c:*

λ	i	
	Ti	Ni
3599.25	2.3	2
3722.70	2.3	3
5712.07	2	3
5715.30	2.3	3

The first of these also occurs in the spectrum of cobalt. Rowland makes the wave-length of the second line 3722.71, and attributes the line partly to nickel and partly to titanium and iron.

As impurities of titanium I have had to strike out only the two lines:

λ	i	
	Ti	Ni
3609.45	1.2	2.3
3619.61	1.2	5

of which the last is also a very strong line in the spectrum of cobalt, while the first is a weak line in this spectrum and must therefore be attributed to nickel. The following lines therefore remain as doubtful:

λ	i	
	Ti	Ni
3697.05	1	1
4025.26	1	1.2
4164.80	1	1
4330.85	1.2	2
4480.72	2	2
4560.08	2	2
4655.82	2	1.2

4. TITANIUM AND MANGANESE.

Manganese furnishes, as the following table shows, only a small number of approximate coincidences with titanium:

Ti λ	Ti i	Mn λ	Mn i	Remarks
3599.25	2.3	99.25	1	Perhaps divided. The intensity of the Ti line too great.
3601.31	1	01.40	1	Divided; λ Ti < λ Mn. Hard to see.
41.48	2.3	41.55	1	Widely separated.
85.30	4	85.25	1	Coinc. To be stricken from Mn.
3741.19	3	41.15	1	Coinc. Belongs to Ti. The Mn line has variable intensity on different plates.
3829.81	1 +	29.83	2.3	Appear to be divided; but λ Ti > λ Mn.
34.06	1.2	34.00	3.4	Probably divided, and λ Ti > λ Mn.
60.61	1.2	60.55	1	Mn missing from comparison plate.
61.89	1.2	61.85	1.2	Probably divided.
3904.95	3.4	04.90	1 +	Perhaps divided.
26.48	2 +	26.55	2.3	Widely divided; λ Ti < λ Mn. $\Delta\lambda > 0.07$.
82.62	2.3	82.70	2	Widely divided.
4059.07	2 −	59.05	3.4	Cannot be divided. The Ti line is perhaps an impurity.
65.23	2	65.20	2	Perhaps divided, and λ Ti > λ Mn.
90.73	1	90.75	1 +	Both lines missing from comparison plate.
4123.42	1.2	23.40	1.2	Coincident.
23.68	2.3	23.65	1.2	Probably divided, and λ Ti > λ Mn.
28.20	1.2	28.25	1	Mn missing.
31.38	1.2	31.30	2.3	Widely separated.
37.39	2 +	37.40	1.2	Coincident.
66.45	2 −	66.35	1	Mn missing.
4211.85	1.2	11.95	2	Divided; λ Ti < λ Mn. $\Delta\lambda < 0.10$.
4388.22	1.2	88.22	1	Coincident.
4455.48	3	55.50	3	Coincidence apparently exact.
57.59	3.4	57.70	3	Widely separated; λ Ti < λ Mn.
62.26	1.2	62.20	4	Divided; λ Ti > λ Mn.
4766.48	1.2	66.55	3.4	Fully separated.
5481.64	2.3	81.60	3	

As common to both metals are to be regarded the lines λ 4455.48 and λ 5481.64 only. The line λ 4059.07 probably belongs to manganese and not to titanium. The following lines are still doubtful:

λ	i Ti	i Mn
4123.42	1.2	1.2
4137.39	2	1.2
4388.22	1.2	1

5. TITANIUM AND CHROMIUM.

These two spectra had already been compared in connection with the investigation of the spectrum of chromium. Most of

the approximate coincidences which were found in the first revision proved to be merely apparent, since a separation of the lines was effected in all but a comparatively few cases. Of these lines the following are to be regarded as common to both spectra:

λ	i	
	Ti	Cr
3558.66	.2	2.3
4122.31	2	2
4295.91	3.4	2.3
5225.15	2.3	3

The following lines are possibly due to a third metal existing as an impurity in both titanium and chromium:

λ	i	
	Ti	Cr
3556.32	1.2	1
3696.00	1	1
3786.44	1.2	1
3836.22	1	2
4261.75	2	1.2

6. TITANIUM AND CALCIUM.

Of the spectral lines of calcium only a few of the most intense are found here and there on my plates. Their differentiation from the titanium lines is in general not a difficult matter, since they usually appear as pointed lines only in the neighborhood of the carbon points. Most of them could therefore be eliminated with the iron lines in the first review of the spectrum. A comparison with Kayser and Runge's wave-length catalogue of calcium lines gave only the following coincidences:

Ti		Ca	
λ	i	λ	i
3653.61	5	53.62	3
4318.83	3.4	18.80	5
4355.44	1	55.41	4

In this, as in other tables, I have reduced the estimates of the intensity of the calcium lines to my own scale. The last of these lines is perhaps to be removed from the titanium spectrum as an impurity due to calcium; the others are apparently to be ascribed to both metals. Kayser and Runge have also observed the first line in the spectrum of strontium, although they attribute it to calcium.[1] Rowland likewise attributes the line λ 4318.83 to calcium,[2] and gives its wave-length as 4318.82.

7. TITANIUM AND STRONTIUM.

In the wave-length table for strontium given by Kayser and Runge, are the following lines, which have nearly identical positions with lines in the titanium spectrum:

Ti		Sr	
λ	i	λ	i
3477.33[3]	2.3	77.33	2
4338.05	3	38.00	4
5238.77	2	38.76	6

The last line is one of the strongest in the strontium spectrum. The coincidence with the titanium line is quite certainly only an accidental one, as with titanium there is no trace of the other principal lines of strontium, like those at λ 5156.37, 5257.12, 5404.48, and 5481.15. So in the cases of the other two lines, which are sharp in titanium, but diffuse and even unsymmetrically defined in strontium, the coincidence must certainly be merely accidental.

8. TITANIUM AND BARIUM.

The approximate coincidences of lines in these spectra, which I have found with the aid of Kayser and Runge's observations, are as follows:

[1] *Spectren der Elemente*, Abth. IV. 31.

[2] *A. and A.*, 1892, p. 231.

[3] 3467.33 in the original, by an obvious misprint.—*Ed.*

Ti λ	Ti i	Ba λ	Ba i		Remarks
3525.28	1.2	25.23	4	± 0.10	Diffuse; reversed.
3593.61	2	93.58	3	.15	Diff. toward red.
3861.89	2	61.87	2	.10	Diffuse.
4291.32	2	91.32	3	.05	
4325.30	3	25.38	2	.05	
4489.24	2.3	89.50	3	.50	Diff. toward violet
4900.08	3	00.13	5	.05	
5381.20	1.2	81.25	1	.50	Diff. toward red.

Of these coincidences, the second, sixth and last may be at once regarded as accidental, both on account of the great uncertainty in the wave-lengths of the barium lines, and their unsymmetrical diffuseness. According to Rowland, the barium line λ 4900.13 falls between the titanium line (λ = 00.10, Rowland) and a line of yttrium at λ 4900.31, and is therefore independent of both. The three lines λ 3861.89, 4291.32 and 4325.30 appear to have the same character in both metals, and may, on account of their nearly identical intensity, if the coincidence is exact, be common to both. Only in the case of the first line is the existence of an impurity due to barium to be considered; but since none of the other principal lines of barium can be found in the titanium spectrum, and taking into account the considerable uncertainty in the position of the barium line, the coincidence may probably be regarded at only an apparent one

9. COMPARISON OF TITANIUM WITH THE REMAINING METALS HITHERTO INVESTIGATED BY KAYSER AND RUNGE.

The immediate result of this comparison was, that not a single coincidence with titanium is found in the metals magnesium, zinc, mercury, aluminium, thallium, lead, antimony, sodium, potassium and cæsium. On the other hand, a few approximate coincidences with titanium lines are found in the spectra of lithium, rubidium, indium, tin, bismuth and cadmium, which, if they are exact, demonstrate nothing more than this fact, which is repeatedly met with in the preceding comparisons, that two

metals may accidentally emit identical radiations; for, since most of the principal lines of the comparison metals are completely lacking in the titanium spectrum, it is extremely improbable that the lines in question are due to the presence of these metals as impurities. The coincident lines are given in the following table, together with the limits of error in their wave-lengths which are assumed as possible by Kayser and Runge:

λ	i	λ	i	Remarks	
4273.45	1.2	73.44	3	± 0.20; diff. toward red	Li
3587.27	2	87.23	4	.05; reversed.	Rb
4511.32	1.2	11.44		.10; reversed	In
3801.25	1	01.16	4	.05	Sn
3981.91	3.4	81.92	2	diff. toward red	Cd
5298.61	2	98.52	2	.20; diff. toward red	Bi
4492.70	1.2	92.79	3	.03	Bi
3596.17	2.3	96.26	3	.03	Bi
3510.98	3	11.00	3	.03	Bi

(*To be continued.*)

Minor Contributions and Notes.

NOTICE.

The attention of subscribers is called to the fact that The Astrophysical Journal is not issued in September. The next number will be published in October.

NORMAL SPECTRUM OF THE ZINC ARC.

A photographic map of the arc spectrum of Zinc has recently been prepared by Professor Crew, by the use of metallic electrodes in motion. (*Philosophical Magazine*, October 1894.)

The main purpose of the map is to show the physical character of the Zinc lines which Ames, Kayser and Runge have measured and studied in such a masterly manner. (*Wied. Ann.* Bd. 43 pp. 385–409.)

The part of the spectrum mapped includes the region between w.l. 6500 and w.l. 2100. The photographs are made with a Rowland grating of 14438 lines to the inch and 10 feet radius. The series includes eight plates, on each of which, in addition to the Zinc spectrum, is photographed the arc spectrum of Iron, and a scale of single Ångström units, seventy to the inch. The figures are put on this scale by the hot needle method devised by Mr. O. H. Basquin (Astrophysical Journal, February 1895.) The scale will be found to be correct to within a fraction of an Ångström unit; more accurate readings, if desired, can be made by interpolation in the Iron spectrum which is practically not displaced at all with reference to the Zinc.

On the back of each plate is printed a table of wave-lengths for the Zinc lines. The wave-lengths of most of the impurity lines are also tabulated and identified.

The metal used in the arc is the ordinary "chemically pure" zinc of commerce.

With two exceptions the entire series lies in the spectrum of the second order, each plate covering 800 Ångström units and overlapping the preceding plate by half its length, so that each region of the spectrum appears on two different plates. Since it is manifestly impossible

to give each line its proper exposure, the preference has generally been shown to the weaker lines, with the result that all of Kayser and Runge's lines with perhaps two exceptions may be seen on the original negatives, while all but perhaps five of them may be seen on the silver prints. Naturally the impurity lines are very weak, and many that appear on the negative cannot be seen on the print.

The following details will perhaps indicate what has determined the exposure in each case.

LIST OF PLATES.

No. of Plate	Region of Spectrum	Remarks
1.	6500. to 5200.	First order. Shows the very intense and characteristic red line of the spark and flame spectra at w.l. 6362.5; photographed in the arc by Rowland, not given by Kayser and Runge. The great density of the photograph near w.l. 5600 is not due to real intensity of the spectrum in this region, but to the special sensitiveness of an orthochromatic plate for rays of a corresponding wave-length.
2.	5700. to 4900.	Shows the line of longest wave-length measured by Kayser and Runge, *viz.*, w. l. 5182.20.
3.	5300. to 4500.	Shows the extraordinary intensity of the blue triplet as compared with all its neighbors. The "ghosts," which are almost invariably produced by a diffraction grating, but which are generally so faint that they do not show on photographs, are in this case quite conspicuous.
4.	4900. to 4100.	Shows the reversal of the blue triplet, the homologue of the green triplet of Magnesium.
5.	4500. to 3700.	Shows incidentally the care necessary in the identification of lines, since here the *impurity* lines in "chemically pure" Zinc far outstrip the Zinc lines in both number and intensity.
6.	4100. to 3300.	A region practically barren of Zinc lines, and one which may, therefore, be useful in mapping the spectra of non-conductors in cored Zinc electrodes, especially as this region is largely filled with Cyanogen lines.
7.	3700. to 2900.	Shows the first triplet (hitherto observed) of the "*erste Nebenserie*" of Kayser and Runge, together with two highly characteristic companion lines, all five strikingly reversed.
8.	3600. to 2100.	First order. Illustrates the crowding together of homologous groups at the ultra-violet end, a fact which has been used to explain a similar distribution of lines in the solar spectrum. Shows also w. l. 2138, the most characteristic single line in the whole spectrum of Zinc, the homologue of Mg 2852, which is, correspondingly, the most characteristic single line in the whole spectrum of Magnesium.

These silver prints are each mounted on white cardboard 2½ x 12 inches.

The set of eight photographs will be sent, postpaid, to any address for three dollars.

All orders and remittances should be sent to Business Agent Northwestern University, Evanston, Illinois, U. S. A.

The spectrum of the Magnesium arc, similar to the above in style, is also sold at three dollars.

The spectrum of the Aluminum arc will be published shortly.

July 1896.

THE DETECTION OF THE LINES OF WATER VAPOR IN THE SPECTRUM OF A PLANET.

THE recent discussion in this journal of the best form of instrument for observing the lines of water vapor in the spectrum of Mars leads me to describe some observations of my own, which seem to have a direct bearing on the question.

In the early part of 1895 I had been photographing the lower spectrum of Jupiter with an instrument of considerable power; namely, with the prism train of the Allegheny spectroscope, described in *Astronomy and Astrophysics*, 12. The distance between the *b* and D lines on the plate was about one inch, and the definition of the photographs was excellent. The spectrum of the planet extended to some distance below D, and therefore included the region of the principal band δ of aqueous vapor.

On these plates the spectrum of the planet seemed to be identical with the sky spectrum, which was photographed close beside it either on the day preceding or the day following the exposure. This result, though it agreed with Vogel's visual observations of the same part of the spectrum, induced me to make some experiments on the relative values of high and low dispersion for detecting the presence of water vapor lines. On March 3, when the sky was clear, I photographed the solar spectrum at intervals with the large spectroscope, until the Sun was near the western horizon, and at the same time observed the spectrum visually with a small direct-vision spectroscope. A comparison of the results showed that at low altitudes of the Sun the telluric bands near and above D were exceedingly strong in the small instrument and were by no means conspicuous on the photographs, where they were (partially, at least) resolved into separate fine lines.

These observations therefore support the view which is held by Mr. Campbell (and I think by most other spectroscopists), that a high resolving power is not advantageous for detecting bands composed of numerous closely packed fine lines. The same conclusion may be arrived at by comparing any group of fine lines in the solar spectrum as seen with a powerful instrument, or on a map like Rowlands', with the same group in a small spectroscope.

The chief difficulty in photographing the lower spectrum of a planet arises from the peculiar curve of sensitiveness of an orthochromatic plate. The curve falls very abruptly near D, and only a very short range of spectrum in this region can be given the proper density. Full exposure, which tends to equalize the density, is a partial remedy, but the difficulty is always a serious one.

JAMES E. KEELER.

MR. JEWELL'S RESEARCHES ON THE SOLAR ROTATION.

We are informed by Mr. Lewis E. Jewell of Johns Hopkins University that his recent work in measuring a large number of lines in photographs of the solar spectrum has brought out a new and remarkable peculiarity in the law of the solar rotation. It is found that there is a difference of several days in the rotation periods of the outer and inner portions of the Sun's atmosphere, the period increasing as the photosphere is approached. The measures also show the equatorial acceleration to be much the greatest for the outer portions of the atmosphere. At the lower levels the acceleration is small, there being little difference in the periods for different latitudes. It is further found that the carbon (cyanogen) lines and the shaded portions of H and K take their rise very low down in the solar atmosphere. Mr. Jewell is at present engaged upon the reductions of the measures. His detailed account of the investigation will appear in a later number of this JOURNAL.

HARVARD COLLEGE OBSERVATORY, CIRCULAR NO. 7.

TEN NEW VARIABLE STARS.

THE following list of new variable stars includes, as described below, three whose variability was discovered or suspected elsewhere and has been confirmed at this observatory. The successive columns

give the name of the constellation, the designation in the *Durchmusterung* catalogues, the approximate right ascension and declination for 1900, the number of plates examined, the magnitude when brightest and when faintest as derived from the photographic charts, and the authority for the variation, the letters H. C. O. indicating that the variation was found at this observatory.

Constell.	Design.	R. A. 1900	Dec. 1900	No. Pl.	Mag. Br.	Mag. Ft.	Authority
Horologium..	.....	$2^h\ 22^m.4$	$-60°\ 0'$	21	9.7	<12.7	H. C. O.
Canis Minor..	$+5°$ 1797	7 43 .4	$+5\ 40$	42	10.3	11.3	H. C. O.
Pyxis	-24 7693	9 0 .7	$-24\ 41$	13	8.9	11.1	Thome
Hydra	-22 7652	9 46 .4	$-22\ 32$	32	8.2	10.1	H. C. O.
Centaurus ...	.....	11 16 .1	$-61\ 20$	70	9.2	<12.9	H. C. O.
Libra	-19 4047	15 6 .5	$-19\ 25$	70	9.2	<12.9	H. C. O.
Scorpius	-35 11829	17 35 .7	$-35\ 12$	31	10.7	11.6	H. C. O.
Cor. Austr....	-37 12782	18 34 .3	$-37\ 56$	67	8.9	<11.8	H. C. O.
Sagittarius ...	-33 14076	19 10 .0	$-33\ 42$	89	6.1	<11.3	Markwick
Sculptor	-30 19448	23 3 .7	$-30\ 41$	47	8.0	8.9	H. C. O.

The first star, R. A. $2^h\ 21^m\ 39^s$, Dec. $-60°\ 8'.0$ (1875), has a period somewhat greater than 300 days.

The second star, $+5°$ 1797, was faint on two plates taken in 1886, and on the photographs taken since then shows variations which though small appear to be real.

The third star, $-24°$ 7693, was suspected of variability by Thome (*Annals Cordoba Observatory*, **16**, p. xxxviii). As he distinguished this star by an exclamation mark, photographs of it, and of six others similarly marked, were examined here by Miss E. F. Leland and the variability of this star was established.

The fourth star, $-22°$ 7652, was found by Miss L. D. Wells from a comparison of two chart plates in her search for stars having large parallaxes, proper motions, or variations in light. This star has been suspected of variability by Espin and Thome. Their names, however, are not included in the above table since almost all red stars have been suspected of variability, and attempts to confirm suspected variables have failed in a large number of cases. It would obviously be unfair when an astronomer publishes a long list of suspected variables to regard him as the discoverer of any which on later evidence may prove to be variable. It is extremely improbable that the light of the Sun, or of any star, is absolutely constant, although the change is in the great majority of cases beyond our present means of measure-

ment. If the distinction between real and suspected variability is not maintained, the person first stating that all stars are variable might claim the discovery of all variables subsequently found. It will be seen that this star stands on a wholly different basis from the preceding star, since in that case the variability suspected by Thome was the reason for the further examination of this object. This star is -22° 2739 in the *Bonn Southern Durchmusterung*. Its spectrum was found to be of the fourth type by Dunér.

The fifth star, R. A. $11^{h}15^{m}1^{s}$, Dec. $-61^{\circ}\,11'.4$ (1875), has maxima represented by the formula J. D. 2,411,100 + 162 E. The next maximum will accordingly occur on October 21, 1896.

The sixth star, -19° 4047, ι Libræ, appears in four of the catalogues of stars measured with the meridian photometer. In Vol. XIV. measures on seven nights gave the magnitude 4.87. In Vol. XXIV., Table I., three nights gave the magnitude 4.36. In Vol. XXIV., Table IV., three nights gave the magnitude 5.02, and in Vol. XLIV., unpublished, three nights gave the magnitude 4.37. The discordance is so great as compared with that of other stars contained in these catalogues that variability of the star seemed to the writer the only reasonable explanation. Accordingly, visual observations were at once undertaken with the meridian photometer, and also by Argelander's method. By the latter method, Mr. Wendell soon confirmed its variability, finding it two grades fainter than θ Libræ on May 19, and two grades brighter than the same star on June 1, 1896.

The eighth star, -37° 12782, has an approximate period of 136 days.

The ninth star, -33° 14076, is a very remarkable object. It was one of a list of forty-two stars suspected of variability sent here for examination by Colonel E. E. Markwick of Gibraltar. A report was sent to him that an examination of several photographs failed to show any sign of variability. A few days later an object having a peculiar spectrum was discovered by Mrs. Fleming. All the plates of the region were examined and its variability established. It was about to be published in *Circular* No. 6 when it was found to be identical with the star of Colonel Markwick. It was accordingly reported to him for announcement, but he has kindly authorized its publication here. The photographs show that on eight nights in the summer of 1889, on six nights in 1890, on six nights in 1891, on five nights in 1892, on twelve nights during April, May, June, and July of 1893 the variation of

light of this star was comparatively small and irregular. Colonel Markwick's first two observations on July 14 and 19, 1893 showed it of the seventh magnitude and a little brighter than the adjacent star -33° 14068. In August he found it fainter than this star, and by September 12 it was invisible and below the ninth magnitude. A photograph taken here on September 11, showed that it must then have been fainter than the magnitude 9.6, and on October 23, fainter than 11.3. Photographs taken on April 30, May 30, July 8, August 7, August 10, September 12, September 15, November 12, and November 13, 1894, gave the magnitudes 10.9, 10.3, 9.4, 8.6, 8.3, 7.5, 7.6, 6.4 and 6.4 respectively, thus showing a nearly regular increase in its normal brightness which it retained with irregular variations on twenty-seven nights in 1895. Observations by Colonel Markwick, beginning on August 20, 1894, lead to a similar result. The spectrum of this star is peculiar, and contains bright lines which show evidence of change.

The variation of the tenth star, -30° 19448, is small and irregular.

The spectra of the first, fifth, eighth, and probably the tenth stars are of the third type, having also the hydrogen lines bright. The second and seventh have spectra of the fourth type. These six variables were found by Mrs. Fleming in her regular examination of the Draper Memorial photographs.

MISCELLANEOUS NOTES.

A large number of observations has been made with the meridian photometer to determine the forms of light curve of stars of the Algol type. S Antliæ has hitherto been regarded as belonging to this class and is of interest from the shortness of its period, $7^{h}\ 46^{m}.8$, and since it was said to retain its full brightness for less than half of the time. It is difficult to reconcile the last condition with the theory that the variation is due to a dark eclipsing body. One hundred and seventy-seven measures, each containing sixteen photometric settings on S Antliæ, were made with the meridian photometer and give eight normal points. A smooth curve with only two points of inflection can be drawn through these normal points, the greatest deviation being 0.02 magnitudes. From this it appears that S Antliæ is not a star of the Algol type, that its light is continually changing, and that it belongs to the class of variables of short period like δ Cephei and η

Aquilæ. An interesting feature of this curve is that the time of increase occupies 0.62 of the entire time of variation, the increase of light being slower than the diminution.

U Pegasi appears to be second in this respect; since, according to the *Astronomical Journal*, **16**, 108, its time of increase is 0.55 of the entire time, and that of other short period variables varies from 0.20 to 0.33. On the other hand, the time of increase is about 0.17 for No. 18 of the variables discovered in the cluster Messier 5 (see *A. N.*, **140**, 285).

The star β Lyræ is commonly regarded as a variable of short period of the same class as the above. Observations of its spectrum, however, show that two or more bodies, revolving round each other, are present. The light curve found by Argelander may be closely represented by assuming that the primary minimum is caused by the eclipse of the brighter body by the fainter, and the secondary minimum by a similar eclipse of the fainter body by the brighter. This star should, therefore, be taken from the class of ordinary short period variables and included among the stars of the Algol type.

Mr. Backhouse calls attention to his announcement in the *Observatory*, **17**, 402 of the variability of $+0^{\circ}939$, announced in the ASTROPHYSICAL JOURNAL, **2**, 198, and to his observations which indicate a period of not more than a year. Variability also suspected by Espin.

The variable star, R Microscopii, is identical with $-29^{\circ}17235$.

EDWARD C. PICKERING.

HARVARD COLLEGE OBSERVATORY, CIRCULAR No. 9.

STARS HAVING PECULIAR SPECTRA.

A LIST of stars having peculiar spectra is given in the annexed table. They were all discovered by Mrs. Fleming in her regular examination of the Draper Memorial photographs. The number of stars of the third type is so large, now amounting to several thousands, that it has not been thought worth while to announce them, but to reserve them for a full list of stars having peculiar spectra to be published in a volume of the *Annals*. In the following table, the designation of the star in the *Durchmusterung* catalogues is given in the first column when it occurs in that work. The approximate right

ascension and declination for 1900 are given in the next two columns, followed by the *Durchmusterung* magnitude. The fifth column gives the character of the spectrum, followed by additional remarks when required.

Designation	R. A. 1900	Dec. 1900	D.M. Mag.	Description
— 8° 1099	5h 17m .6	— 8° 45′	7.0	Peculiar.
.....	7 38 .3	— 70 7	....	Peculiar.
.....	10 52 .0	— 59 51	....	Peculiar. Resembles η Carinæ.
— 37 7905	12 24 .0	— 37 42	8.8	Type IV.
— 34 11675	17 18 .5	— 34 6	10.	Type V. Gal. long. 320° 56′, lat. — 0° 30′.
— 39 12196	17 58 .2	— 39 20	9.0	Type IV.
.....	18 17 .5	— 13 46	....	Type V. Gal. long. 345° 14′, lat. — 1° 34′.
.....	18 22 .2	— 16 53	....	Type V. Gal. long. 343° 2′, lat. — 4° 04′.
— 25 13170	18 23 .2	— 25 19	7.6	$H\beta$ bright.
— 38 12843	18 23 .4	— 38 29	9.5	Type IV.
— 31 15954	18 40 .0	— 31 28	9.2	Peculiar.
— 29 15574	18 52 .4	— 29 38	8.9	Peculiar.
— 40 13448	19 37 .1	— 40 40	9.0	Peculiar. Resembles η Carinæ.
— 18 5480	19 40 .6	— 18 24	9.1	Type IV.
+ 85 332	19 43 .8	+ 85 9	9.2	Type IV.
.....	20 15 .6	+ 16 25	....	Gaseous Nebula. Gal. long. 26° 13′, lat. — 12° 09′.
— 12 5755	20 26 .2	— 12 13	9.2	Type IV.
+ 5 5223	23 44 .0	+ 5 50	8.7	Type IV.

Of the seven stars whose spectra are here announced as of Type IV., the first, second and seventh are normal. The spectra of the others contain rays of much shorter wave-length than ordinary fourth type stars. The spectra of two faint objects announced as peculiar in the *A. N.* **135,** 195, have been shown by recent and better photographs to belong to a different class from that there given. One of these, whose approximate position for 1900 is R. A. 17h 38m.2, Dec. — 46° 3′, announced as a stellar object having the spectrum of a gaseous nebula, proves to have a faint continuous spectrum in which the hydrogen lines $H\beta$, $H\gamma$, $H\delta$, $H\epsilon$, and $H\zeta$ are bright, and the bright line at 5007 is absent, so that it more nearly resembles the spectrum of η Carinæ. The second object, — 33° 13537, R. A. 18h 39m.3, Dec. — 33° 27′ (1900), announced as of the fifth type, proves to have the spectrum of a gaseous nebula.

EDWARD C. PICKERING.

July 9, 1896.

ON A NEW METHOD OF PREPARING PLATES SENSITIVE TO THE ULTRA-VIOLET RAYS.[1]

VI. THE DEVELOPMENT.

THE development is carried out solely with pyro and soda prepared according to Dr. Eder's formula (vide *Photographie mit Bromsilber-gelatine und Chlorsilber-gelatine*, 4th edition, 1890, p. 294).

I.	Crystallized sodium sulphite	100 grams
	Pyrogallic acid	14 "
	Sulphuric acid (to neutralize the alkaline sulphite)	6 drops
	Water distilled	500^{cc}

The sulphite is dissolved in the water, the acid added and finally the pyro.

II.	*Crystallized* sodium carbonate	50 grams
	Water distilled	500^{cc}

If anhydrous carbonate be used only half the above will be required.

The developer should only be used greatly diluted; otherwise spots and fog appear on the plates. I use for each volume of pyro and soda solution 3 to 6 volumes of ordinary water and some potassium bromide. The image appears in about 20 to 30 seconds, and is finished in two to three minutes. If the development is carried on longer fog comes on, notwithstanding the dilution of the developer, and sometimes even earlier. If the image is to show clear glass then the plate must be washed as soon as the fogging begins and fixed immediately afterwards. In my experiments the fogging frequently began after the development had gone on for 90 to 100 seconds. If the negative does not come up completely in this time another plate must be taken with longer exposure. There is no use in trying to attain the object by forced development.

It is only by observing this precaution that a clear picture can be obtained with these plates which are sensitive to the ultra-violet.

For spectrum photographs, which particularly require delicate delineation, especially for bringing out closely crowded lines, I have lately followed another method of developing. I take no heed of what appears on the plate—it would, in fact, soon be impossible, because the lines could not be seen in the development on account of their exceeding fineness; so I leave the plate in the developer for a certain time which I have ascertained by experience. It is true, I do not suc-

[1] Continued from **3**, 394.

ceed with a single trial. As a rule the first negative I take in this way does not suffice, because the lines are too broad, and lines lying together are either massed together or insufficiently separated. In such cases I take another negative. Although I keep to the original exposure I shorten the development by some seconds. In this way I frequently obtain, but only after the third or fourth exposure, line pictures of a fineness which I cannot obtain with ordinary development. This mode of procedure takes up a good deal of time, but the beauty of the resulting negatives richly repays the great expenditure of time and trouble.

The fogging of the plate can be restrained with potassium bromide, but care is necessary with it. *Potassium bromide exerts a decided influence on the size of the silver particles which form the negative or the so-called "grain" of the plate.* I take 5 to 10 drops of 10 per cent. solution of potassium bromide for 60 to 180^{cc} water, 20^{cc} pyrogallic acid and 20^{cc} soda solution.

With gelatine emulsions, it is assumed that the grain of the emulsion is of the same size as the grain of the image. If this is not strictly the case with such plates, as is shown by the microscope, it is still less so with plates sensitive to the ultra-violet rays.

The negative grain of a plate sensitive to the ultra-violet is in most cases a combination of several, often even of a great many grains of emulsion which together form a blackish-brown cluster of varying form and size. The size of this cluster depends on the nature of the sensitive coating and on the composition of the developer. It will be increased by silver iodide, but still more by potassium bromide in the developer. In general, silver bromo-iodide in a developer containing potassium bromide gives a coarser negative grain, while silver bromide in a developer free from bromide gives a finer one.

How much the size of the grain sometimes depends on the potassium bromide is shown by the following example. I cut a bromo-iodide plate into three parts and, without exposing to light before doing so, developed the first part without bromide, the second with a small addition of potassium bromide, the last with five times as much, and each until a strong fog appeared. The three plates show on a transparent ground a series of negative grains in turn 0^{mm}.02, 0^{mm}.14, and 0^{mm}.27 in size, besides it is true, many smaller grains also. All these grains have the form of a disk, and the distance between them increases with their diameter. These plates, especially the coarse-grained ones,

quite produce the impression that the silver bromide, which at first covered the ground of the plate, had been used up in forming the larger clusters. Whether, and to what extent, the solubility of the silver bromide in potassium bromide is connected with the enlargement of the grain I must leave undecided, because I have not occupied myself further with this question.

The gelatine appears to have some influence on the formation of the usually angular or round-shaped negative grain. Silver bromide containing agar-agar gave me coarse moss-shaped forms.

The size of the negative grain of a bromo-iodide plate developed with a developer containing potassium bromide depends further on the nature of the cause which brings about the decomposition of the developable silver haloid. An unexposed plate developed to the point of fogging gives the coarsest grain, and an exposed plate the finest; between them lies the grain which is given by a moderately exposed sensitive film.

If the washing of the plate after the first drying is omitted, then it always carries with it a small quantity of potassium bromide after leaving the silver solution and also some potassium nitrate. In this case the appearances are more or less similar to those which follow the addition of potassium bromide. I have not studied the effect of potassium nitrate on development. There is no fear of free potassium iodide in the sensitive film, because during the precipitation of the silver haloids it will be completely changed into silver iodide and potassium nitrate before the bromide can separate itself out.

If potassium iodide is added to the developer the image appears very quickly—seldom, however, without fog. If the development is not stopped at the right time the fog increases until the image disappears from sight, notwithstanding that it is still easily visible by transmitted light on account of its unusual density. In most cases the fog begins at the edges of the plate, so that the middle of the plate is also more transparent after fixing.

The quickness with which the image appears and its great intensity, in consequence of which more details are visible in the developer than on a less intense plate, led me at first to the belief that potassium iodide would allow of a notable decrease of exposure. But comparative trials showed that the gain is small. The increase of density is of greater importance. Only the lines developed with potassium iodide have such fuzzy edges that they are badly adapted for sharp measure-

ments. Their grain is enlarged, and partly on account of the foggy ground, not sharply defined. In other cases, plates which are wanting in intensity and too transparent under the microscope to permit of being distinctly focused answer the purpose better if developed with potassium iodide than is otherwise possible.

But little iodide should be added to the developer, as otherwise the plates may become covered in a few seconds with such a thick fog that only the high lights of the image remain perceptible. I use a 1 per cent. solution and for each 3^{cc} of pyro solution 1 to 2 drops of the iodide.

Potassium bromide checks the fogging tendency of the iodide, but only slightly. With 6 drops of bromide solution (1:20) to 3^{cc} pyro solution the fogging caused by one drop of potassium iodide (1:100) could barely be checked.

Potassium chloride lessens the fog, but also the sensitiveness and intensity. The disadvantages, unfortunately, outweigh the advantages. It is so at least with silver-bromide, to which in this case my experience is limited (one trial).

A developer containing gelatine tends to a fine-grained image and also checks the formation of fog. Toward the end of the development potassium bromide may be added without fear of enlarging the grain. If the bromide be present from the commencement the image acquires great clearness, but comes up slowly. If the plate contains silver-iodide the grain enlarges under the influence of the bromide. My developer contains 2^{cc} of solution of gelatine (1:50) to 3^{cc} of pyro (one trial).

Ammonia employed as a preliminary bath heightens the sensitiveness and intensity of the silver bromide. The lines will be clearer, the ground of the plate lighter, although it shows larger spots than an unbathed plate does. This mode of sensitizing does not answer in practice because the bathing (15 minutes in 150^{cc} water and 1^{cc} ammonia) and the subsequent drying, take up too much time (one trial).

The general result of my experiments in developing leads to the use of a largely diluted developer and little bromide with a good exposure, but above all short development.

VII.—THE FIXING.

The fixing is done in a solution of hyposulphite of soda (1:4), and proceeds much quicker than with ordinary dry plates. My small

plates for photographing the spectrum in a vacuum readily fix in a few seconds. It is only when the film contains iodide that minutes are required. Silver iodo-bromide plates should always be kept horizontal and lie in the fixing solution face downwards, so that the silver-laden solution may fall quickly to the bottom and make room for fresher and more active solution. For this purpose evaporating dishes are most suitable, and if chosen of suitable size they have the further advantage that the plates as they lie can only touch the dish at the edges and corners and not on the surface, and can more easily be laid hold of and taken out of the bath without damage — an advantage not to be underrated with small sizes. I prefer to employ two baths, the second for the after-fixing. In this way the negative does not require so much washing and keeps better. By long use the bath works more slowly, especially in fixing plates containing iodide. In this case a new bath should be made.

Plates without a binding material require very careful handling to prevent the image from floating away. In this case the film side must naturally be placed uppermost. When all the bromide is dissolved the best plan is to remove the fixing solution with a syphon. The dish must not be shaken; it may be inclined a little at the last, as much as is necessary to run off the remaining fluid from the plate. The same care is necessary during the subsequent washing. When it is allowable, such films may be set fast with a gelatine bath after development. The fixing will be made very much easier thereby.

VIII. — WASHING AFTER DEVELOPMENT AND AFTER FIXING.

If the plate has been coated with gelatine and the silver bromide also contains gelatine, then it will stand a pretty strong stream of water without damage. In any case it can be washed without hesitation in abundantly flowing water. Greater care is necessary if there is no gelatine coating or if the sensitive bromide contains no gelatine, especially if it is in a thick layer. In this case standing water is better. As a rule, the film stands better than one would expect.

After development I wash only a few seconds, and when it is desired to suddenly stop the development I plunge the plate into the fixing bath without washing. I keep fixed plates in a stream of water from one to two minutes, and this is generally enough to remove the fixing salt. Larger sizes will take more time. I work

with small plates only, and these dry on blotting paper in two or three minutes. Most of the water runs down to the bottom of the plates, and is absorbed by the paper. The rest I shake off or let it soak into a slip of blotting paper which I put on the edge of the plate.

Care must be taken not to touch the film with the finger while it is wet. It is very easily damaged in this way, although it will resist a stream of water.

If the plate is required to be dried off quickly, which is desirable for the better preservation of the sharpness of the image, then after the water has drained off I hold it close to a stove or lamp-chimney. There is no fear of the film melting, as with a gelatine dry plate.

IX.—THE NEGATIVE IMAGE.

The negative image forms a lusterless relief of a dark gray or brown color. By rubbing with the finger, or better with some hard substance, it becomes like polished silver. Even dusting with a soft brush will often cause glittering silvery lines to appear. If the silver bromide contains no gelatine the surface of the image is much more tender, and the employment of a brush to remove dust, etc., is quite impossible. (With plates containing gelatine the silver film worked over with a burnisher gives, after a few strokes, a bright, silvery film which is so resisting that it may be highly polished with a leather and rouge.) The image may be further protected by a coat of varnish or gelatine, but not without damage to the sharpness. This is the case at all events with line spectra. The conditions are not the same as with ordinary dry plates, in which the image is within the gelatine film; in the new plates it is more like a small silver rod on the gelatine coating. The silver particles which compose this little rod lie thickly and closely together in the best of my pictures. Hence they show such extraordinary sharpness under the microscope. As soon as the varnish runs over these small rods it causes a swelling which naturally must have some injurious influence on the definition of the edges of the lines upon which it falls.

X.—THE INTENSIFYING.

Plates with a very fine grain sometimes fail in density. In this case they must be intensified. I hoped at first to be able to use silver intensification with advantage, but the trials did not answer my

expectations. I have, however, obtained satisfactory results by bathing the plates in a solution of mercury bichloride 1 : 50, well washing, and then treating them with dilute ammonia at 1 : 10, followed by copious washing. As a rule the intensifying of spectrum negatives is not to be recommended, because it deprives them more or less of their original character and delicacy. The image should always derive the necessary density from the developer.

XI.—SENSITIVENESS.

I have at present very few observations ont his point. Until quite lately I did not have the vacuum apparatus necessary for the proper treatment of this subject. Such of my results as are of importance for the purposes of this paper I give below.

Silver bromide is, as already stated, made more sensitive by the presence of silver iodide and gelatine. The same result occurs whether it settles in gelatine or if the grains of silver bromide are in contact with gelatine on one side only. Its sensitiveness is considerably increased thereby.

Plain glass plates were coated on one half with gelatine, and silver bromide was allowed to settle on them as before described, so that one half of the plate had a coating of gelatine with silver bromide above it, while the other was coated with the bromide alone. The two halves touched each other in a straight line which equally divided the image of the spectrum into two halves in the direction of its length. Each exposure gave a complete spectrum on both halves of the coating. When exposed to the spectrum of the Sun the gelatine half showed itself certainly four or five times more sensitive than the glass half. (If the gelatine coating shows any bubbles that have burst and left plain glass, the precipitated silver bromide will be less sensitive in such places and show lighter points and circular spots. Bromide containing gelatine does not show this defect.)

These pictures were repeated with silver bromide that had been precipitated in presence of ammonia, as well as with some that had been precipitated from a solution containing gelatine. Attention was also paid to the thickness of the film of silver bromide. With the silver bromide that had been treated with ammonia the same difference between the two halves appeared as before, but, on the other hand, with that containing gelatine the gelatine substratum, as might have been expected, produced no effect. The explana-

tion of this is easily understood; the sensitiveness of the silver bromide is so greatly increased by its being precipitated from gelatine and surrounded by it that the very much weaker action of the gelatine substratum has no visible effect. The same thing is observed with silver bromide free from gelatine, when it is exposed in films of greater thickness. Hence it is also easy to see that in this case the photo-chemical action of the rays of light only reaches the outer layer of the film which does not come under the influence of the bromine-absorbing action of the gelatine (H. W. Vogel), like the particles of bromide deposited directly upon the gelatine substratum. In this case the action on the two halves of the plate must be exactly the same.

The new plates are not very sensitive to sunlight. At a height of 120 meters above mean sea level (Leipzig) I obtained with a June Sun wave-length 2939.7, and with highly sensitive dry plates under the same conditions, with only a third of the exposure, wave-length 2937.0.[1]

With an exposure of such duration (forty minutes) as was necessary for this, the spectrum on the ultra-violet sensitive plate breaks off sharply as an opaque band of action at wave-length 2973.8 and runs on further from there in distinct lines on a clear ground as far as wave-length 2939.7. This clear glass ground in the neighborhood of the most refrangible ultra-violet rays of the Sun is an advantage of the new plates. Under the same circumstances ordinary plates give thick fog, in which the most refrangible lines become first of all indistinct, and if an effort is made to photograph them more clearly by longer exposure they disappear entirely. On account of this defect the observation of the most refrangible rays of sunlight on ordinary plates is made considerably more difficult. At the same time, they are always to be preferred on account of their greater sensitiveness.

The new plates can only come into question in cases where they excel both in intensity and in sensitiveness. This first occurs at wave-length 2200, and from this point onward their sensitiveness

[1] Both lines belong to the extension of the ultra-violet solar spectrum discovered previously by Herr Oskar Simony. I took their wave-lengths from the drawing published by A. Cornu in the *Comptes Rendus* (111) of this part of the spectrum extending to wave-length 2922.2, which was made from Simony's original photographs.

increases. Consequently their greater working power is more in their unusual intensity, and is based on the fact that, in consequence of their small sensitiveness for the less refrangible rays, there is nothing to hinder their being exposed for a long time without becoming thickly fogged as ordinary dry plates do. The origin of this fog is diffused light arising from the inside of the prisms and lenses of the spectroscopic apparatus, of which the principal part consists of rays for which gelatino-silver bromide emulsion is much more sensitive than pure silver bromide.

Since the use of gelatine so distinctly improved my pictures of the less refrangible rays of the new spectral region there was no reason for excluding it in the opening up of the remaining part of the spectrum as far as wave-length 1000. My attention was first of all attracted by its presence about the limits of action of the plates employed. Circumstances have unfortunately not yet allowed me to approach more closely a solution of this question.

The resumption of my experiments on plates should quickly settle the behavior of pure silver bromide with regard to wave-length 1000, and, as the following considerations will show, there is some hope of success.

If one considers that gelatine, even in a thickness of only $0^{mm}.00004$, sensibly weakens the rays of wave-length 1852, and that in even much thinner layers it apparently stops all photographic action of ordinary dry plates near wave-length 1820, and on the other hand that the course of its absorption curve between $\lambda 2200$ and $\lambda 1820$ shows no increase, but rather a lessening of its transparency for the rays of the more strongly refrangible region, it is quite surprising that in spite of this it should be practicable to photograph the extensive region of the smallest wave-lengths, as I have ventured to designate the part of the spectrum lying between 1852 and 1000, by means of gelatine. An explanation of this is to be found only in the sensitizing action of the gelatine, which possibly gets the upper hand in the struggle with absorption, and begins to lose it where the range of action of the new plates ends.

Under these circumstances it may be expected that the discovery of the unknown spectral region beyond wave-length 1000 is reserved for the pure silver haloid. Gelatine will, however, in this case also hardly be superfluous, because when used as a substratum it forms the only possible means of increasing the sensitiveness.

XII.— THE KEEPING QUALITIES OF THE PLATES.

I have kept plates prepared in different ways for a long time in order to test their keeping qualities from time to time. They were kept unpacked in a light-proof cupboard, and consequently were not protected against the action of the atmosphere. From my experience with gelatine emulsions I was afraid they would show unevenness in their coating, and, above all, increased fog around their edges and a greater development of the imperfections of their surfaces. Pictures taken with them show, however, the contrary. The plates work even more cleanly after keeping than when freshly prepared, and some kinds were even more sensitive. I did not, however, make comparative trials with the sensitometer. My experience is founded only on the photographic pictures of the new rays beyond 1850. According to this the new plates can be kept quite as long as ordinary dry plates. Compared with those coated with an emulsion containing silver oxide and ammonia they show even far superior keeping powers.

ON THE EMPLOYMENT OF PLATES SENSITIVE TO THE ULTRA-VIOLET.

The plates were intended from the very commencement for photographing the spectrum, and have hitherto been used for that purpose only. How they answered (and not less, in what points they still failed) is shown in the foregoing account, and further in my former paper I have pointed out their good and bad qualities impartially, because I did not wish to promise more than they could be trusted to perform. I therefore consider disappointments in their use as entirely excluded from discussion.

As a measure of their actual capabilities the spectra 11 and 12 on Plate V. of the above-mentioned paper[1] may be referred to. It may, however, be remarked that the definition of these spectra has suffered from defects in the crystal of the fluor-spar prism employed, and that the same plate exposed to the diffraction spectrum has given a clearer picture. A proof of this is afforded by my enlargements to more than three hundred times of the diffraction pictures of the rays 1620.

The sharpness of my negatives has here and there led to the belief

[1] *Sitzungsberichte K. Akad. d. W. Wien*, Bd. CII, Abth. II, *a:* "*Uber die Photographie der Lichtstrahlen kleinster Wellenlängen*," Part 2, 1893.

that the new plates can be used advantageously for astro-photography. Against this, however, there are two important obstacles, the want of sensitiveness and the formation of a round grain in the negative.

For the rays of light with which astro-photography has to do the plates hitherto in use are many times more sensitive than the new ones. The use of the latter could only be thought of with considerably prolonged exposures. Astro-photography, however, requires the exact opposite — shortening of the exposure. Further, the disk-shaped negative grain arising from chemical fog, as has already been fully explained, is so like the picture of a star that some of my plates have quite the appearance of a picture of the starry heavens. Under such circumstances mistakes could hardly be avoided in star pictures. In that case, too, the precautionary measures that have hitherto been employed for recognizing defects of the plates will not have the desired effect, because the grain alluded to often comes out very strongly. Both defects outweigh the advantage of greater sharpness of image to such a great extent that the new plates cannot be recommended for astro-photography, and for professional photography, still less. The only use they might find would be for line reproductions. The perfect sharpness with which they reproduce lines and their absolute opacity would certainly place them in the first rank for this, if the preparation of faultless films over large surfaces did not only involve considerable difficulties, but was also too costly and took up too much time to pay.

I have not used them for portrait or landscape photography, but for the same reasons, and still more on account of the want of half-tones, they are quite unsuitable for such purposes.

They completely fulfil only their original object: the observation of the rays beyond wave-length 2200. But for this purpose they are at present unrivaled.

V. SCHUMANN.

Lord Rosse's lecture before the Royal Institution, on the radiant heat from the Moon during the progress of an eclipse, has been printed in pamphlet form. The author gives an exceedingly interesting review of his early observations, and compares his results with the later work of Langley and Boys, by which they are in general confirmed. An unexpected result, and one which is still unexplained, though confirmed by subsequent observations, was the fact that the Moon did not regain

its full heat after an eclipse. From the low coefficient of transmission of glass for lunar heat, Lord Rosse inferred that most of the heat is derived from solar rays which have been absorbed and re-radiated by the surface of the Moon, and not merely reflected by it, and Langley's subsequent measurements in the lunar heat spectrum led to the same conclusion.

The lunar heat phase-curve determined by Mr. Very agrees nearly with that of Lord Rosse, though he had the latter curve to guide him. (It is not clear how this could affect the form of the curve). The greatest heating effect is not found after the time of full Moon, as might be expected, but for some cause (possibly accidental), a little before it.

The apparatus used by the author consists of two thermopiles, each with a condensing mirror, swung in front of a three-foot reflector, and it is evidently much less sensitive than that employed by Langley, who measured the distribution of heat in the lunar spectrum with a beam only ten inches in diameter. The radiomicrometer can be used only in a fixed position, and therefore in connection with a heliostat; experiments with a bolometer were only partially successful, and Lord Rosse thinks that a thermo-couple, with sufficiently sensitive galvanometer, would be better adapted to his purposes than either of these instruments.

Reviews.

NEW BOOKS ON THE SPECTROSCOPE.

La Spectroscopie. Par JULIEN LEFÈVRE, Professeur à l'École des Sciences et à l'École de médecine de Nantes. Small 8vo, pp. 188. Paris: Gauthier-Villars et fils.

La Spectrométrie. Appareils et mesures. Par JULIEN LEFÈVRE, Professeur à l'École des Sciences et á l'École de médecine de Nantes. Small 8vo, pp. 212. Paris: Gauthier-Villars et fils.

Die Spectralanalyse. Von Dr. JOHN LANDAUER. 8vo, pp. viii + 174. Braunschweig: Friedrich Vieweg und Sohn, 1896.

THE small books by Professor Lefévre form two of the numerous volumes of the *Encylopédie scientifique des aide-memoire*, published under the direction of M. Léauté, Membre de l'Institut, and therefore seem intended to serve as guides to the student, or to the general reader seeking technical information. The first volume is devoted to spectroscopic results, the second to instruments, and to results which depend upon exact measurement; but the distinction between qualitative and quantitative work is not a very satisfactory basis of classification in spectroscopy, and in the arrangement of these volumes it is by no means carefully observed.

The preface to *La Spectroscopie* informs us that the author has undertaken to bring together results scattered through numerous memoirs, especially those of recent date, and that "Le lecteur trouvera donc ici . . . . tout ce qui se rapporte aux spectres d'émission et d'absorption des corps simples, au spectre solaire, aux spectres invisibles, aux mouvements et à la constitution des astres." After this assurance we are somewhat surprised to find that many, if not most of the recent results of spectroscopic investigations are conspicuously absent. Thus, the chapters on the spectra of the elements represent a stage of progress which has long been passed. They are mainly devoted to the pioneering work of Lecoq de Boisbaudran, and contain nothing

later than the measures of Thalén. No reference is made to the researches of Kayser and Runge, Rydberg, Eder and Valenta, Hasselberg or Rowland. The wave-lengths are from old tables, and no hint is anywhere given that corrections are required to reduce them to the modern standard. In the identification of solar lines no advance beyond the work of Ångström is indicated. In solar spectroscopy Hale's photographs of prominences and faculæ have no place. The spectroscopy of stars and nebulæ is that of Secchi's time, and the only astronomical spectroscope described and illustrated in the book is of value only on account of a certain amount of historical interest, and as an example of what should be carefully avoided in designing a modern instrument. There is no reference to the researches of Vogel and Scheiner on the motion of stars in the line of sight, or to Pickering's photographs of star spectra and discovery of spectroscopic binaries. The chapter on the infra-red spectrum does not mention the wave-length determinations of Paschen and of Rubens, nor that on the ultra-violet spectrum the important investigations of V. Schumann. Were it not for a few references to recent results that have been published in French journals, the book might have been written twenty years ago.

In the second volume the theory of the spectroscope is developed, and many forms of instruments are described and illustrated. Considerable space is given to the half-prism and to the Thollon couple. Here the treatment is interesting, and, in some respects fairly satisfactory. But the theory is developed entirely from the standpoint of geometrical optics (except, of course, in the case of the diffraction grating); hence there is no reference to the resolving power of a spectroscope, the most significant of its properties. Hence, also, the lack of a guiding principle, by which the student can estimate the relative efficiencies of the different forms of instruments described, and decide which of them is best for any particular purpose. In the absence of such a principle the author himself frequently falls into error, as for example in the statement that the same results can be obtained with three or four compound half prisms as with fifteen or twenty prisms of the ordinary form.

The account of the results of spectroscopic measurements, which forms the latter half of the book, contains much more of modern work than the preceding volume; but between recent results and the early investigations to which the greater part of these two volumes is devoted,

there is a gap which cannot be bridged over without a more attentive study of English, German and American scientific literature.

Dr. Landauer's handbook more nearly represents the present state of spectrum analysis. It is a reprint, with some alterations and additions, of an article contributed by the author to the *Neues Handwörterbuch der Chemie* of Drs. Fehling and Hell, and prominence has naturally been given to the chemical aspect of spectroscopy. The greater part of the book is devoted to the spectra of the elements and their compounds, and to the excellent treatment of this subject the value of the book is mainly due. Under each substance is given an account of its spectral peculiarities, with a brief historical notice; the tables of wave-lengths embody the results of the most recent measurements, and are followed by copious references to original sources of information. All wave-lengths are expressed in tenth-meters, and, when necessary, have been reduced to Rowland's scale. The most useful instruments for laboratory purposes, including the concave grating spectroscope, are described and illustrated, but the theory of these instruments is very lightly touched upon.

The astronomical applications of the spectroscope occupy only a few pages, which bear evidence of having been compiled by one who has little practical familiarity with the subject. They are however of minor importance from the standpoint of the author, and a satisfactory treatment would in any case be impossible with the same restrictions as to space. The present state of science is in general fairly well represented, and in one place, on page 155, where the photography of the corona in full daylight is mentioned as an accomplished fact, the author even runs a little ahead of the times.

J. E. K.

Ueber das Spectrum von Mira Ceti. Von H. C. Vogel. Sitz. d. K. Akad. d. W. Berlin, **17**, 395–399, 1896.

In this short paper Professor Vogel gives the results of measurement of a number of photographs obtained by Professor Wilsing with the Potsdam spectrograph. The upper part of the spectrum closely resembles that of the Sun; in the lower part, toward F, the deviation from the solar spectrum becomes more pronounced, and the bands characteristic of the type IIIa begin to appear. All the hydrogen lines are bright, and very strong and broad, with the exception of $H\epsilon$,

the place of which is occupied by the strong absorption line H of calcium. Professor Vogel accepts Miss Clerke's explanation of this remarkable spectrum, remarking however that the existence of a relatively cool layer of calcium vapor over the hydrogen envelope is conceivable as representing only a temporary state of the star's atmosphere, and that it is important to ascertain whether the bright lines are visible at other times than those of the star's maximum brightness.

A slight displacement of the hydrogen lines toward the red was suspected, but could not be verified on account of the small scale of the photographs. No absorption lines accompanied the bright hydrogen lines, except in the case of $H\zeta$, which resembled the same line in β Lyræ. No other bright lines were shown on the photographs.

The paper concludes with a table of wave-lengths and comparisons with solar lines.

Notes on the Nebular Theory in Relation to Stellar, Solar, Planetary, Cometary, and Geological Phenomena. By WILLIAM FORD STANLEY. 8vo, pp. 260. London: Kegan Paul, Trench, Trübner & Co., 1895.

ACCORDING to a statement in the preface, this book is based upon a series of papers which were regarded by orthodox authorities as too speculative for communication to the learned societies. The author therefore makes no very high claim for them, although his purpose—to establish a modified form of the Nebular Theory of Laplace on certain new ideas and calculations of his own—is sufficiently ambitious, and would seem to require the application of somewhat more rigorous methods.

After a few pages devoted to the views of Wright, Kant, Laplace, and later philosophers, the author proceeds to develop his own ideas. As it is difficult to account for the phenomena presented by the nebulæ, considering their extreme tenuity and the accepted dimensions of the atom, a still further subdivision of matter is postulated. Matter in this ultimate state of dissociation exists as a "pneuma," and the dissociation-unit is a "pneumite." The pneumites are all of the same size. They have one vibration period only; they have the same capacity for heat, and many other properties in common, which are minutely described and illustrated in chapter ii. It is rather disheartening to the reader to find that "the state and associations of such pneumites

will now be considered as the groundwork of the nebular theory to be proposed."

In fact, in the development of the theory which follows we have a detailed history of what may or may not be the actual processes of nature. While some of the author's ideas are novel and interesting, and may prove to be of value, others certainly run counter to well-known mechanical and physical laws. The last few chapters deal with geological rather than cosmical theories.

The style is unattractive, and frequently obscure. The reader finds his patience tried by whole sentences that have to be read more than once in order to extract their meaning, and he cannot avoid a feeling of relief when he lays the book aside.

Observations de l'Éclipse Totale du Soleil du 16 Avril, 1893. H. DESLANDRES. (Mémoire extrait des *Annales du Bureau des Longitudes*, t. V.)

THE eclipse of the present month lends additional interest to the report presented by M. Deslandres at the beginning of the year to the Bureau des Longitudes, and now fresh from the press of Gauthier-Villars. Two expeditions were sent to Senegal by the Bureau des Longitudes for the purpose of observing the phenomena of the total eclipse of 1893. One of them, under the leadership of M. Deslandres, was to devote its entire attention to astrophysical observations, while the other was to confine its programme to those of astronomy of position. The present report gives the details of the methods employed in obtaining the results already published in the *Comptes Rendus*. The volume of seventy-seven pages is divided into four chapters, of which the first three describe the object and organization of the expedition, the journey and establishment of the station at Fundium, and the results obtained, while the fourth is devoted to general remarks on the solar atmosphere. The work is illustrated by three heliogravure plates, which are reproductions of photographs of the eclipse station and of the inner and outer corona.

The object of the expedition comprised investigations (*a*) of the form and brightness of the corona, (*b*) of its spectrum, especially in the ultra-violet region, and (*c*) of its rotation. For the direct photography of the corona four objectives were employed, ranging in aperture from

$0^m.08$ to $0^m.12$ and in focal length from $0^m.60$ to 3^m. One of these, an objective by Zeiss with a field of 30°, was used with the idea of revealing a possible intra-Mercurial planet. Of the eighteen successful negatives obtained, those made on plates of mean sensitiveness gave the best results, while on the most sensitive plates the background of sky is too intense and the details are less clearly visible. Certain of the latter plates, however, which received short exposures, show perfectly the prominences and the inner corona. Three of the negatives have upon them a series of squares due to progressively increasing exposures to a standard lamp, made before the eclipse. On one of these plates there have been traced three curves, the points of which have respectively the same brightness as the squares corresponding to the exposures 4^s, 8^s and 12^s. After taking into account the diameter of the objective, and its absorptive effect, it was found that the part of the corona lying between circles $3'$ and $9'\ 30''$ from the limb equaled in brightness 0.18 of a "bougie décimale" placed at a distance of one meter. The simplicity of this photometric method is a strong point in its favor, but we unfortunately have the testimony of some who have used it in tropical countries that the results obtained in this way cannot always be given very great weight.

The negative obtained with the Zeiss wide angle objective covered a field of 30°, and clearly showed the planets Venus and Jupiter, the latter 9° distant from the Sun. It could not be determined whether other black points upon the plate were stars or photographic defects, and M. Deslandres consequently recommends that hereafter such objectives be used in duplicate, so that the results may be compared.

In his remarks on the forms of the prominences photographed during the eclipse, M. Deslandres has paid some attention to the question of the "white" prominences of Tacchini. His conclusion, based upon a comparison of the portrait lens and objective prism photographs, is that if prominences are accompanied by dust emitting a continuous spectrum, the image of the dust cloud is identical with that of the gas. He does not agree with Professor Schaeberle that prominence photographs taken without an eclipse fail to show the essential details of structure, but maintains the opinion also recently expressed by the reviewer in these pages, that if suitable precautions are taken the images will be very similar to those made during totality.

As for the form of the corona, the images obtained with the portrait lenses were found to agree closely with the South American

photographs of Schaeberle, showing that the changes which are known to take place in the coronal structure do not ordinarily occur within a few hours. The corona of 1893 agreed with those of 1871 and 1882 in demonstrating that the curved polar rays and marked equatorial extension which are characteristic of minima of spot activity are replaced at times of maxima by approximate uniformity of extent in all directions.

In the section on the composition of the coronal light M. Deslandres reviews at some length the observations made at previous eclipses before describing his own work. In all, five spectrographs were employed; three of them received light from the mirrors of a polar heliostat, upon the axis of which a fourth was mounted. The fifth was carried on a small equatorial mounting. With the spectrograph having one flint prism a photograph was obtained showing a continuous spectrum crossed by thirteen bright lines between λ 5000 and λ 3800. Of these four are of unknown origin, while the remainder belong to hydrogen, calcium or helium. No dark lines were shown. Nearly the same portion of the spectrum was included in a photograph taken primarily for the purpose of determining the rotation of the corona, with a spectrograph having three flint prisms. On this plate the spectra of regions between 3′ and 10′ from the limb on opposite sides of the Sun were photographed for comparison. Although equal exposures were given in the two cases, fifteen bright lines were shown on the east and but eight on the west side of the Sun. The calcium (H and K) and the hydrogen lines were strongest on the west side, but other lines of unknown origin were equally strong on both sides. Moreover, a comparison of the bright lines photographed with the one prism and the three prism spectrographs, which received light from different parts of the corona, shows an apparent difference in the gases represented in the two cases. The ultra-violet spectrum as far as λ 3089.2, or about the limit of the solar spectrum, was photographed with a spectrograph having a single prism of Iceland spar. Here, as in the two previous cases, no dark Fraunhofer lines were obtained. The intensity of the spectrum was greatest in the blue, and diminished rapidly toward the ultra-violet. A comparison of this spectrum with one of the disk, obtained with the same apparatus, showed that the decrease of intensity toward the ultra-violet was more rapid in the former plate. Thus the maximum of intensity of the coronal spectrum is probably displaced toward the red, on account of

the lower temperature of the coronal region. Thirty-eight bright lines, most of them of unknown origin, were photographed between λ 3628.1 and λ 3089.2.

The third piece of work with which M. Deslandres busied himself was an attempt to determine spectroscopically the velocity of rotation of the corona. Of the two spectroscopes employed the first had a 4-inch Rowland grating and quartz lenses of $1^{m}.30$ focal length. With this instrument, on account of the faintness of the spectra, no results were obtained. The second spectroscope, having three flint prisms, was carried by a 6-inch equatorial mounting. The slit, placed parallel to the solar equator, was so arranged that each half could be alternately exposed to the corona, the solar image being moved between the exposures so as to bring points in the corona respectively 10′ distant from the east and west limbs of the Sun, upon the center of the east and west halves of the slit. The negative obtained with this instrument showed images of the H and K lines sufficiently strong for measurement. The lines given by opposite parts of the corona were displaced with reference to each other an amount corresponding to a difference in velocity of $6^{km}.8 \pm 1^{km}.2$. M. Deslandres concludes from this that the corona at the equator closely follows the disk in its motion, *i. e.*, that the corona moves as though it were a solid rigidly attached to the photosphere. Various objections have already been raised by several writers to the validity of this conclusion, to some of which M. Deslandres replies. It is not likely that the displacement can be attributed to the change of temperature during totality. The apparatus was well protected against temperature variations, and laboratory experiments made under similar conditions revealed no sensible displacement. The objection that the H and K lines are not truly coronal, but are due to diffusion of the light of the chromosphere and prominences, is a much more serious one. M. Deslandres points out in the first part of his memoir that the atmosphere was very hazy during the eclipse, so that we may conclude from the experience of earlier eclipses that the diffusion must have been very appreciable. As much of the diffuse light in each part of the corona observed must have come from the neighboring chromosphere and prominences, there must have resulted a certain relative displacement of the lines somewhat less than that observed by M. Deslandres. If, as seems not unlikely, the probable error of the measures is larger than the value given, the result would be left much in doubt if it is held that the H

and K lines were due to diffusion. Professor Lockyer, from the observations made by the English party at the same African station, concludes that the H and K lines do not properly belong to the coronal spectrum.

Moreover the remarkable results on the solar rotation recently obtained by Mr. Jewell, briefly referred to on another page, can hardly be reconciled with M. Deslandres' conclusion that the photosphere and corona rotate together like a rigid mass. It is to be hoped that a repetition of the experiment will soon be made by M. Deslandres. If, as is suggested in the memoir, it is found possible to use the fourth spectrum of a 6-inch grating, and to determine the motion in the line of sight by measuring the inclination of the coronal lines with reference to fixed lines of comparison, as Professor Keeler and M. Deslandres have done in the case of Saturn's rings, the mode of rotation of the corona should be placed beyond a doubt. With such dispersion it may also be possible to draw some trustworthy conclusions regarding the rotation of the corona from the unsymmetrical diffuseness of the edges of the coronal lines, as the author also points out.

The remainder of the memoir is devoted to a general discussion of solar phenomena and a review of various solar theories. M. Deslandres finds great difficulty in accepting Professor Schaeberle's explanation of prominences, as the structure required by this theory is not often met with in daily observations of these objects. He also refers to a fact by no means in harmony with this theory, *i. e.*, the bright lines photographed on the Sun's disk show no such displacements as Professor Schaeberle's conclusions would lead us to expect. M. Deslandres himself believes in the electrical origin of the chromosphere, prominences and corona, an idea which since the very beginning of prominence observations has been held by many solar physicists. The electrical hypothesis is founded upon the apparent fact that the characteristic spectrum of hydrogen can be produced only by means of an electric discharge. It is true that Professor Hartley has recently announced that he once observed the *Hα* line in the spectrum of the flame of a Bessemer converter. "Mais, en examinant avec soin toutes les conditions de l'expérience, on a reconnu que, à ce moment, l'atmosphère ambiante subissait une tempête de neige et par suite une perturbation électrique. Ce fait isolé confirme donc le résultat précédent, et l'on doit admettre comme presque certaine la conclusion suivante: la lumière des protubérances a une origine électrique." Thus does M.

Deslandres (p. 65) dispose of a difficulty in the path of the electrical hypothesis. In the opinion of the reviewer this interesting observation merits further consideration.

The electrical hypothesis explains not only the prominences, but the chromosphere and corona as well. Both give bright line spectra, and are thus allied to the prominences. To account for the electrical condition of these objects M. Deslandres finds an analogy in terrestrial atmospheric electricity. The difference of potential from the top to the bottom of the Eiffel tower varies between 3000 and 30,000 volts. In the hotter and more highly conducting atmosphere of the Sun a much greater (?) difference of potential may reasonably be supposed to exist; whence a continuous luminous discharge, producing the phenomenon of the chromosphere. Prominences correspond to electric storms. Terrestrial atmospheric electricity is generally attributed to the relative motion with respect to the Earth of the various strata of the atmosphere. If the same hypothesis is applied to the Sun it furnishes an explanation of the mode of rotation of the corona observed by M. Deslandres at the eclipse of 1893. For if the atmosphere did not closely follow the disk in its motion, the induction phenomena produced by the relative movements of the gas and floating dust would, according to the law of Lenz, develop opposing mechanical action, and thus tend to bring about uniformity of rotation.

In thus outlining an electrical hypothesis which possesses many interesting and instructive features, M. Deslandres does not discard all mechanical theories. On the contrary, he seeks in the well-known theory of Faye an explanation of the spots, the photosphere and such eruptive prominences as cannot be explained on purely electrical grounds. In the corona other difficulties are encountered. However, the coronal streamers are considered to be similar in nature to the cathode rays produced by electric discharges in rarified gases. The brilliant regions of the chromosphere emit cathode rays which are more active than those of neighboring less-luminous regions: these leave the chromosphere in nearly normal straight lines, and illuminate by phosphoresence the dust scattered through the coronal atmosphere. The curved forms of the rays are due to the magnetic field and to mutual repulsion. M. Deslandres has compared photographs of the corona made at the 1893 eclipse with photographs and drawings of the faculæ made on the same day, with a result similar to that recently obtained by Professor Schaeberle from the same data: the coronal stream-

ers seem to have their origin in the faculæ. It is pointed out, however, that this conclusion is open to considerable doubt, to remove which it will be necessary to devise some method of observing the corona without an eclipse. M. Deslandres has himself proposed a method which may ultimately prove successful: that of photographing the corona with plates sensitive only to light of great wave-length. Hitherto, however, experiments made in this direction (by Dr. Huggins many years ago) have given no valuable results. It is to be hoped that a process of preparing plates suitable for this work will soon be discovered. The bolometric method of mapping the corona proposed by Hale is described by M. Deslandres as being founded "d'une part sur la conclusion précédente relative aux rayons calorifiques, et d'autre part sur les résultats de M. Langley." As a matter of fact, the apparent advantage of the method resides in the fact that it is a strictly differential one, and therefore may perhaps remove the persistent difficulty due to the illumination of our atmosphere. In this method it matters not whether the coronal radiation be of long or short wave-length, provided only that it be sufficiently intense to affect the bolometer. In common with Professor Langley's important work a bolometer is used, but a radiomicrometer or delicate thermopile might quite as well be employed.

M. Deslandres is to be congratulated on having organized and conducted an eclipse expedition which brought home valuable results. His electrical hypothesis, while undoubtedly open to objection, may be regarded as an interesting contribution to the already long list of solar theories. The supposition on which it rests is rather insecure; it offers no explanation of prominence motions in the line of sight, and, to select but one more objection from others that suggest themselves, its manner of accounting for the coronal streamers can hardly be regarded as satisfactory. But it has the merit of indicating new points of view from which future investigations of solar phenomena may profitably be examined.

G. E. H.

Recent Publications.

A LIST of the titles of recent publications on astrophysical and allied subjects will be printed in each number of THE ASTROPHYSICAL JOURNAL. In order that these bibliographies may be as complete as possible, authors are requested to send copies of their papers to both Editors.

For convenience of reference, the titles are classified in thirteen sections.

1. THE SUN.

H. DESLANDRES. Observations de l'Éclipse totale du Soleil du 16 avril, 1893. Mémoire extrait des Annales du Bureau des Longitudes, **5**, 77, 1896.

FÉNYI, J. A new Point of View for regarding Solar Phenomena and a new Explanation of the Appearances on the Surface of the Sun. Ap. J. **4**, 18–38, June 1896.

FÉNYI, J. Protuberanze e facole solari. Mem. Spettr. Ital. **25**, 115–124, May 1896.

FÉNYI, J. Relation concernant deux protubérances observées le 15 juillet et le 30 septembre 1895. Mem. Spettr. Ital. **25**, 47–52, March 1896.

FÉNYI, J. Ueber einen neuen Gesichtspunkt und neue Erklärungen der Erscheinungen auf der Sonne. A. N. **140**, 289–302, 1896.

FLAMACHE, A. Note sur les moyens d'observer les protubérances solaires. Bull. Soc. Belge d'Astron. **1**, 83–91, 1896.

GUILLAUME, J. Observations du Soleil, faites à l'observatoire de Lyon pendant le premier trimestre de 1896. C. R. **122**, 1181–1183, 1896.

KOBOLD, H. Resultate der Beobachtungen der Sonnenfinsternisse 1890 Juni 16–17, 1891, Juni 6 und 1893 April 16. A. N. **140**, 225–227, 1896.

LEWITZKY, G. Sonnenfleckenzählungen auf der Kais. Universitäts-sternwarte Juriew (Dorpat). A. N. **140**, 263–265, 1896.

LOCKYER, J. NORMAN. The Total Eclipse of the Sun. Nat. **54**, 197–199, 1896.

MASCARI, A. Sulle grande protuberanze solare osservata all Osservatorio di Catania il 15 luglio 1895. Mem. Spettr. Ital. **25**, 55–56, March 1896.

RADAU, R. Le mouvement propre du Soleil (Review). Bull. Ast. **13**, 169–178, 1896.

RICCÒ e TACCHINI. Immagini spettroscopiche del bordo solare osservate a Catania e Roma nei mesi di gennaio, febbraio e marzo del 1895. Mem. Spettr. Ital. **25**, May 1896.

SARTORIO, G. W. Protuberanze solari osservate nel Reale Osservatorio di Palermo nell' anno 1893. Mem. Spettr. Ital. **25**, 65–81, March 1896.

STRATONOFF, W. Sur deux phénomènes de la physique solaire. Mem. Spettr. Ital. **25**, 87–89, April 1896.

TACCHINI, P. Sulla distribuzione in latitudine dei fenomeni solari osservati al R. Osservatorio del Collegio Romano nel 1° trimestre del 1896. Mem. Spettr. Ital. **25**, 137–143, June 1896.

TACCHINI, P. Osservazioni solari fatte nel 1° trimestre del 1896 al R. Osservatorio del Collegio Romano. Mem. Spettr. Ital. **25**, 107–112, April 1896.

TACCHINI, P. Su di alcune protuberanze e nubi solari osservate nel 1895. Mem. Spettr. Ital. **25**, 59–61, March 1896.

3. STARS AND STELLAR PHOTOMETRY.

ABNEY, W. de W. The Photographic Values of Moonlight and Starlight compared with the Light of a Standard Candle. Proc. R. S. **59**, 314–325, 1896.

CHANDLER, S. C. Third Catalogue of Variable Stars. Ast. Jour. No. 379, **16**, 145–172, 1896.

DUNÉR, N. C. Ueber den veränderlichen Stern Z Herculis. A. N. **140**, 261–263, 1896.

HOLETSCHEK, J. Beobachtungen von veränderlichen Sternen. A. N. **140**, 171–173, 1896.

KOBOLD, H. Erwiderung auf Herrn Anding's Aufsatz in Nr. 3337–8, A. N. **140**, 142–144, 1896.

LOEWY. Sur les recherches faites à l'observatoire de Madison par M. G. Comstock, concernant l'aberration et la réfraction. C. R. **122**, 1157–1159, 1896.

MARKWICK, E. E. Observations of the Variable Stars W, X and Y Sagittarii. M. N. **56**, 381–388, 1896.

MÉRIAU. Densité des étoiles variables du type d'Algol. C. R. **122**, 1254–1257, 1896.

PARKHURST, HENRY M. Notes on Variable Stars,—No 13. Ast. Jour. No. 377, **16**, 132–135, 1896.

PICKERING, E. C. The Cluster Messier 5 Serpentis N. G. C. 5904. A. N. **140**, 285–287, 1896.

PICKERING, E. C. New Variable Stars. A. N. **140**, 173–175, 1896.

ROBERTS, ALEX. W. Supposed New Southern Variable. Ast. Jour. No. 378, **16**, 144, 1896.

SAWYER, EDWIN F. Observations of Variable Stars of Short Period. Ast. Jour. No. 375, **16**, 113–117, 1896.

STUMPE, O. Beiträge zur Bestimmung des Sonnen-Apex. A. N. **140**, 177–191, 1896.

TEBBUTT, JOHN. Star Occultations observed at Windsor, N. S. Wales, during 1895. A. N. **140**, 345–347, 1896.

WEISS, E. Veränderlicher Stern Z Virginis. A. N. **140**, 343, 1896.

WINKLER, W. Sternbedeckungen und Jupitersmonde. A. N. **140**, 265–267, 1896.

YENDELL, PAUL S. Observed Maxima and Minima of Variable Stars. Ast. Jour. No. 375, **16**, 117–118, 1896.

YENDELL, PAUL S. Ephemeris of Variables of the Algol-Type. Ast. Jour. 375, **16**, 120, 1896.

4. STELLAR SPECTRA, DISPLACEMENTS OF LINES AND MOTIONS IN THE LINE OF SIGHT.

ESPIN, T. E. Stars with remarkable Spectra. A. N. **140**, 241–251, 1896.

VOGEL, H. C. Ueber das Spectrum von Mira. Sitz. d. Akad. d. W. Berlin, 395–399, 1896.

5. PLANETS, SATELLITES AND THEIR SPECTRA.

BRENNER, L. Saturne d'après les observations à l'observatoire Manora. Bull. Soc. Astr. France, 194–196, June 1896.

BRENNER, L. Zu den Venus-Beobachtungen der Herren Mascari und Cerulli in A. N. 3329 u. 3331. A. N. **140**, 175, 1896.

BRENNER, L. Sichtbarkeit der Nachtseite des Mercur. A. N. **140**, 347, 1896.

BRENNER, L. Zodiacal Light Observations at the Manora Observatory. Obs'y, **19**, 206–207, 1896.

CAMPBELL, W. W. On Mr. Jewell's Observations of the Spectrum of Mars. Ap. J. **4**, 79–80, June 1896.

CERULLI, V. Le ombre di Venere. A. N. **138**, 366–367, 1895.

FAUTH, P. Ueber das Aussehen des Planeten Jupiter. A. N. **140**, 167, 1896.

FLAMMARION, C. Nouvelles divisions dans les anneaux de Saturne. Bull. Soc. Astr. France, 165–167, May 1896.

GAUDIBERT, C. M. La Photographie lunaire. *d* des Monts Riphées. Un cratère sur la montagne centrale d'Albategnius. A. N. **138**, 363–365, 1895.

GAUDIBERT, C. M. Etudes lunaires, Hevelius. Bull. Soc. Astr. France, 187–190, June 1896.

HARTWIG, E. Beobachtung eines dunklen Flecks auf Jupiter. A. N **140**, 167, 1896.

HOUGH, G. W. Observations of the Spots and Markings on the Planet Jupiter. A. N. **140**, 273–283, 1896.

LAMP, E. Micrometrische Messungen auf Jupiter. A. N. **140**, 169, 1896.

LOEWY et PUISEUX. Sur la constitution et l'histoire de l'écorce lunaire. C. R. **122**, 967–973, 1896.

MARTH, A. Ephemeris for Physical Observations of Mars, 1896–7. M. N. **56**, 394–406, 1896.

PERROTIN, J. Sur les phénomènes crépusculaires et la lumière cendrée de Venus. C. R. **122**, 1038–1042, 1896.

PEYRA, D. Sulle osservazioni di Venere nel 1895. Mem. Spettr. Ital. **25**, 103–104, April 1896.

RICCÒ, A. Righe spettrali atmosferiche osservate sull 'Etna, a Nicolosi, in Catania. Mem. Spettr. Ital. **25**, 127–134, June 1896.

TACCHINI, P. Osservazioni sul pieneta Venere fatte al R. Osservatorio del Collegio Romano nel 1895 e 1896. Mem. Spettr. Ital. **25**, 93–99, April 1896.

VILLIGER, W. Notiz betr. den dunklen Fleck auf Jupiter. A. N. **140**, 319, 1896.

WAUGH, W. R. Fourth Report of the Section for the Observation of Jupiter. Mem. B. A. A. **4**, Part II, 1896.

6. COMETS, METEORS AND THEIR SPECTRA.

CORDER, HENRY. Report of the Section for the Observation of Meteors. Mem. B. A. A. **5**, Part I, 1896.

FRIC, JOSEF und JAN. Photographische Aufnahmen von Cometen. A. N. **140**, 253, 1896.

MERINS, M. El bólido del 10 de Febrero de 1896. A. N. **140**, 169, 1896.

MIRAT, S. B. Analyse d'une des pierres météoriques tombées à Madrid le 10 février 1896. C. R. **122**, 1352, 1896.

NYLAND, A. Die Leoniden von 1895. A. N. **140**, 255, 1896.

SOLA, J. C. Les bolides du 10 février en Espagne. Bull. Soc. Astr. France, 119–122, April 1896.

ST. MEUNIER. Analyse de la météorite tombée à Madrid. Bull. Soc. Ast. France, 122–123, April 1896.

———. Chute d'une météorite à Lesves (Namur). Ciel et Terre, **17**, 117–121, May 1896.

7. NEBULÆ AND THEIR SPECTRA.

BARNARD, E. E. Micrometrical Measures of the Annular Nebula of Lyra. A. N. **140**, 283–285, 1896.

ROBERTS, I. Photograph of the cluster H VII 66 and of the Nebula H IV 75 Cephei. M. N. **56**, 380–381, 1896.

ROBERTS, I. Photograph of the "Owl" Nebula, M 97, and of the Nebula H V 46 Ursae Majoris. M. N. **56**, 378–379, 1896.

8. TERRESTRIAL PHYSICS.

ARENDT, TH. Die Schwankungen im Wasserdampfgehalte der Atmosphäre auf Grund spectroskopischer Untersuchungen. Wied. Ann. **58**, 171–204, 1896.

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HEPPERGER, J. v. Ueber den Einfluss der selectiven Absorption auf die Extinktion des Lichtes in der Atmosphäre. Sitz. d. K. Akad. d. W. Wien, **105**, 173–227, 1896.

KEMPF, P. Review of F. Honsdorff's, Ueber die Absorption des Lichtes in der Atmosphäre. V. J. S. Astr. Gesell. **31**, 2–28, 1896.

SCHUMANN, R. Eine Methode, bei Schweremessungen mit einem schwingenden Pendel den Einfluss des Mitschwingens der Unterlage zu bestimmen. A. N. **140**, 257–261, 1896

9. EXPERIMENTAL AND THEORETICAL PHYSICS.

BECQUEREL, H. Émission de radiations nouvelles par l'uranium métallique. C. R. **122**, 1086–1088, 1896.

COLE, A. D. The Refractive Index and Reflecting Power of Water and Alcohol for Electrical Waves. Phys. Rev. **4**, 50–61, 1896.

COLLIE, J. N. and RAMSAY, W. On the Behavior of Argon and Helium when submitted to the Electric Discharge. Proc. R. S. **59**, 257–270, 1896.

EDITOR OF NATURE. Recent Researches on Röntgen Rays. Nat. **54**, 109–112, 1896.

HAACKE, C. Spektrophotometrische Untersuchungen über die Einwirkung von Salzsäure auf einige Substitutionsprodukte des Fuchsins. (Diss. Tübingen 1894), 8vo., 49 pp.

HUMPHREYS, W. J. and J. P. MOHLER. Effect of Pressure on the Wave-Lengths of Lines in the Arc Spectra of Certain Elements. Johns Hopkins Univ. Circulars, No. 123, **15**, 35–36, 1896.

KELVIN, LORD. On the Generation of Longitudinal Waves in Ether. Proc. R. S. **59**, 270–273, 1896.

LARMOR, J. On the Absolute Minimum of Optical Deviation by a Prism. Proc. Phil. Soc. Cambridge, **9**, 108–110, 1896.

LUMMER, O. Ueber die Strahlung des absolut schwarzen Körpers und seine Verwirklichung. Naturwiss. Rundschau, **11**, Nos. 6, 7, 8, 1896.

MORLEY, E. W., and W. A. ROGERS. On the Measurement of the Expansion of Metals by the Interferential Method. Phys. Rev. **4**, 1–23, 1896.

PASCHEN, F. Ueber Gesetzmässigkeiten in den Spectren fester Körper. Wied. Ann. **58**, 455–492, 1896.

SAGNAC, G. Les expériences de M. H. Becquerel sur les radiations invisibles émises par les corps phosphorescents et par les sels d'uranium. Jour. de Phys. **5** (3^{me} sér.), 193–202, 1896.

SCHMIDT, G. C. Beiträge zur Kentniss der Fluorescenz. Wied. Ann. **58**, 103–130, 1896.

VERY, F. W. Further Considerations in Regard to Laws of Radiation. Ap. J. **4**, 38–50, June 1896.

WIEDEMANN, E. und G. C. SCHMIDT. Spektralbeobachtungen an verdünnten Dämpfen von Metallen und Verbindungen. Sitz. d. Phys. med. Soc. Erlangen, Nov. 1895.

10. THE SPECTRA OF THE ELEMENTS.

BALDWIN, C. W. A Photographic Study of Arc Spectra, II. Phys. Rev. **3**, 448–458, 1896.

EDER, J. M. und E. VALENTA. Ueber drei verschiedene Spektren des Argons (Vorl. Mitteil.). Monatshefte für Chemie (Wien) **17**, 50–57, 1896.

GAMGEE, A. On the Absorption of the Extreme Violet and Ultra-Violet Rays of the Solar Spectrum by Haemoglobin, its Compounds, and Certain of its Derivatives. Proc. R. S. **59**, 276–279, 1896.

DE GRAMONT, A. Sur les spectres des métalloïdes dans les sels fondus. Soufre. C. R. **122**, 1326–1328, 1896.

DE GRAMONT, A. Spectres de dissociation des sels fondus. Métaux alcalins: sodium, potassium, lithium. C. R. **122**, 1411–1413, 1896.

HASSELBERG, B. Untersuchungen ueber die Spectra der Metalle in electrischen Flammenbogen, III., Cobalt und Nickel. K. Svenska Vetens Akad. Handl. **28**, No. 6, p. 44, 1896.

HERSCHELL, A. S. On a Relation Between the Spectrum of Hydrogen and Acoustics. Obs'y, **19**, 232–234, 1896.

KAYSER, H. On the Spectra of Argon. Ap. J. **4**, 1–18, June 1896.

LOCKYER, J. N. On the New Gas Obtained from Uraninite (Seventh Note). Remarks on Messrs. Runge and Paschen's Diffusion Experiment. Proc. R. S. **59**, 342–343, 1896.

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LORD, H. C. The Spectroscope of the Emerson McMillin Observatory. Ap. J. **4**, 50–54, June 1896.

LUNT, JOSEPH. Stellar Photography with Small Telescopes without Driving-Clocks. Nat. **54**, 84–86, 1896.

HALE, GEORGE E. and F. L. O. WADSWORTH. The Modern Spectroscope. XIX. The Objective Spectroscope. Ap. J. **4**, 54–79, June 1896.

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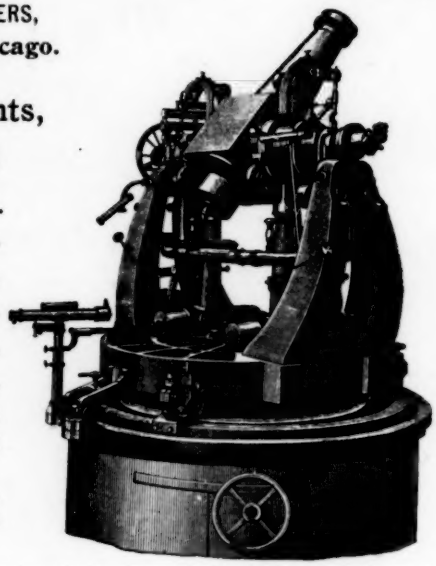

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